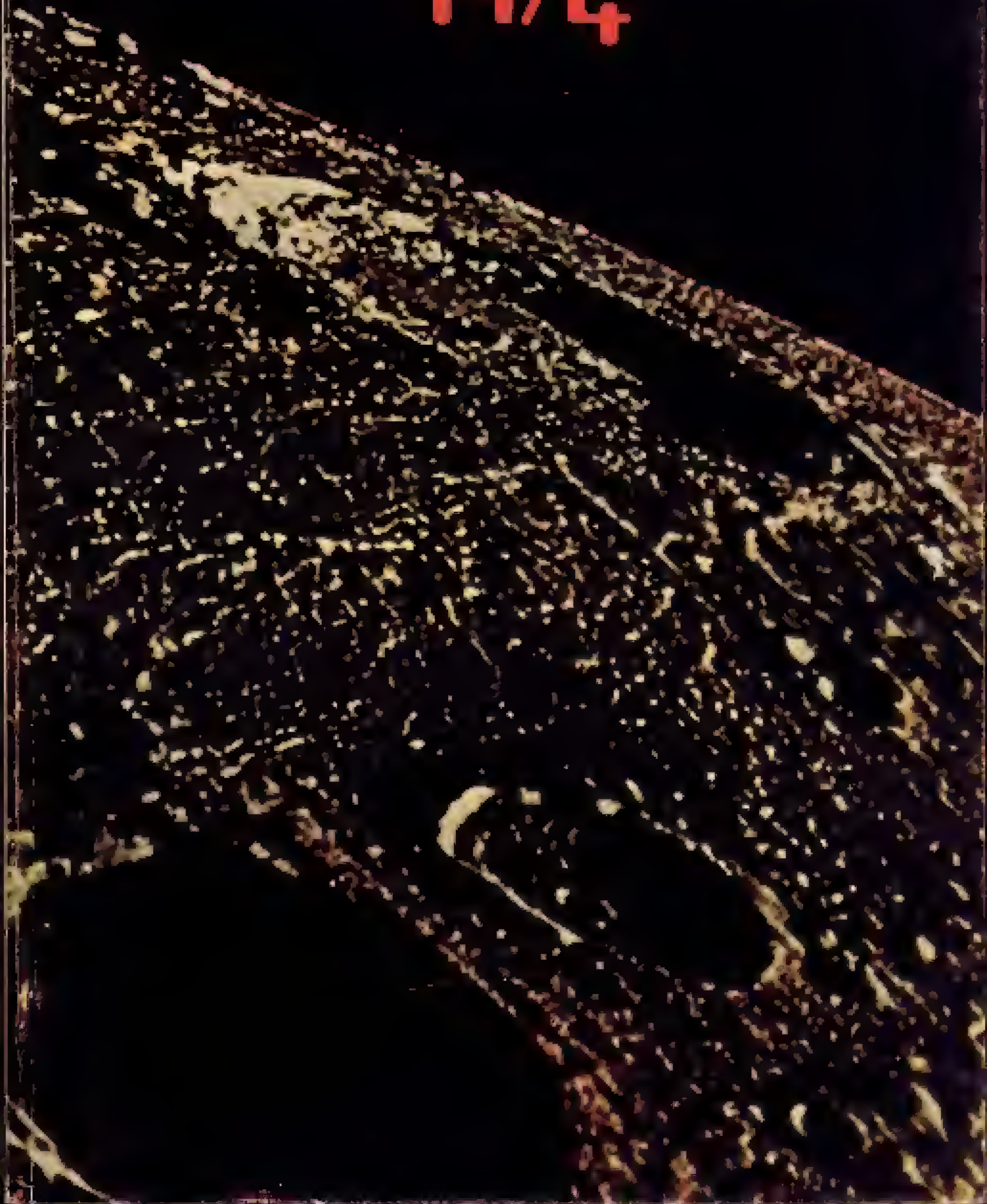
Edited by Patrick Moore

Yearbook of Astronomy 1974



10/72

1974
Yearbook of Astronomy

Edited by

PATRICK MOORE

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Contents

Editorial · 7

Index to Articles in Previous *Yearbooks* · 9

Preface · 13

PART ONE: EVENTS OF 1974

Notes on the Star Charts · 17

The Star Charts · 20

The Planets in 1974 · 46

The Planets and the Ecliptic · 48

Notes on the Planets in the Monthly Diagrams · 50

Phases of the Moon, 1974 · 53

Monthly Notes · 54

The Southern Skies · 111

Eclipses in 1974 · 113

Occultations in 1974 · 114

Comets in 1974 · 115

Meteors in 1974 · 118

Minor Planets in 1974 · 119

Some Events in 1975 · 120

CONTENTS

PART TWO: ARTICLE SECTION

Uranus: The Amateurs' Planet · *G. E. Satterthwaite* · 123

Pioneer 10: the first probe to Jupiter · *H. G. Miles* · 132

Organic Chemistry in the Galaxy · *Simon Mitton* · 141

Magnetic Stars · *V. Barocas* · 147

Highly Reddened Stars · *David A. Allen* · 156

Recent Advances in Radio Astronomy · *Nicholas Tate* · 165

Recent Advances in Astronomy and Astronautics · *Patrick Moore* · 170

PART THREE: FOR STELLAR OBSERVERS

Unpredictable Stars · *Patrick Moore* · 177

Some Interesting Telescopic Variable Stars · 189

Some Interesting Double Stars · 190

Some Interesting Clusters and Nebulæ · 191

PART FOUR: MISCELLANEOUS

Some Recent Books · 195

Our Contributors · 196

Astronomical Societies in Great Britain · 199

Editorial

The *Yearbook* has now been published for thirteen years, and there seems little to add to what has been said in previous Editorials; but I must repeat my thanks to Dr. J. G. Porter, who has made his usual essential contribution, and to both the British and United States publishers. In the Article Section we again welcome some of our familiar contributors and hope that the result will continue to be acceptable!

PATRICK MOORE

Selsey, 1973.

Index to Articles in Previous *Yearbooks*

ALLEN, D. A. *Infra-red Astronomy:* 1969.
—*The Enigmatic Wolf-Rayet Stars:* 1973.
ASHBROOK, J. *Transits of Mercury:* 1970.
BAXTER, W. M. *Observing the Sun:* 1963.
—*The Sun in* 1966: 1966
—*The Sun:* 1968.
—*An Unusual Solar Cycle:* 1972
BEET, E. A. *Astronomy as a Career:* 1963.
BRINTON, HENRY. *A Run-off Observatory:* 1963.
—*Astronomy and Navigation:* 1970.
—*Astronomy and Philosophy:* 1971.
—*Measuring the Universe:* 1965.
—*Telescope Drives:* 1966.
—*Sundials:* 1967.
—*Photography at the Telescope:* 1969.
—*The Tides:* 1973.
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CAMPBELL, D. A. *Astronomical Photography for Amateurs:* 1962.
CATTERMOLE, P. J. *Selenology: or Geology Applied to the Moon:* 1964.
COHEN, M. *Modern Infra-red Astronomy:* 1972.
CROSS, C. A. *The Far Side of the Moon:* 1972.
DALL, H. E. *Eyepieces:* 1963.
—*Cassegrain Reflectors for Amateurs:* 1966.
DE VAUCOULEURS, G. *Problems of Mars:* 1963.
FIELDER, G. *The Craters on Mars:* 1967.
FIRSOFF, V. A. *The Rotation of Mercury:* 1969
FOX, W. E. *The Great Red Spot on Jupiter:* 1964.
GARSTANG, R. H. *The Structure of the Galaxy:* 1962.

GATLAND, K. W. *The Astronautical Outlook:* 1965.

GLASBY, J. S. *Variable Stars:* 1968.

GOODMAN, J. A. *The Edgewise Presentation of Saturn's Rings:* 1966.

GRIFFIN, R. *Automation in Astronomy:* 1962.

—*Variable Stars:* 1963.

GULLEY, R. A. G. *An Observatory Dome for Amateurs:* 1971.

HATFIELD, H. R. *On Seeing:* 1970.

HEY, M. H. *Meteorites and Life:* 1963.

HINDLEY, K. *The Nature of Comets:* 1970.

—*Cosmology: The Debate Continues:* 1970.

HOLE, G. A. *Telescopic Faults:* 1965.

—*Silvering:* 1973.

HYDE, F. W. *The Radio Sun:* 1965.

—*New Horizons:* 1966.

JARRETT, A. H. *Recent Rocket Research:* 1962.

JENNISON, R. C. *Radio and Radar Astronomy:* 1962.

LAURIE, P. S. *Solar Research:* 1962.

—*Harrison, Maskelyne and the Longitude Problem:* 1964.

LEATHERBARROW, W. J. *Amateur Opportunities in Contemporary Lunar Research:* 1971.

LINDSAY, E. M. *Quasi-Stellar Objects:* 1967.

MADDISON, R. C. *Image Converters in Astronomy:* 1967.

—*The Hertzsprung-Russell Diagram:* 1968.

MCCALL, G. J. H. *The Progress of Meteoritics in Western Australia:* 1968.

—*The Mundrabilla Meteorite:* 1973.

MIDDLEHURST, B. *Events on the Moon:* 1968.

MILES, H. *With Mariner II to Venus:* 1964.

—*Meteorite Craters:* 1965.

—*Recent Activities in Space:* 1966.

—*The Van Allen Radiation Belts:* 1967.

—*The Barwell Meteorite:* 1968.

—*The Aurora:* 1969.

—*Why Go Into Space?* 1970.

—1969 *Space-Probes to Venus and Mars:* 1971.

—*Fireballs:* 1972.
—*The 1971 Mars Probes:* 1973.
MIYAMOTO, S. *Clouds in the Atmosphere of Mars:* 1965.
—*Mantle Convection in the Moon:* 1968.
MITTON, SIMON. *Seyfert Galaxies:* 1973.
MOORE, PATRICK. *The Origin of the Universe:* 1962.
—*Introduction to Mars:* 1965.
—*Introduction to Saturn:* 1966.
—*Mars: a Sterile Planet?* 1969.
—*Test Objects:* 1971.
—*Variable Stars for the Binocular-Owner:* 1970.
MOSELEY, T. J. C. A. *A Simple Home-Made Refractor:* 1968.
—*First Steps in Amateur Astronomy:* 1969.
MUIRDEN, J. *A Cycle of Clusters and Nebulæ:* 1965.
—*A Cycle of Double Stars:* 1966.
—*A Cycle of Variable Stars:* 1967.
—*The Binocular Sky:* 1969.
MURDIN, P. *Stellar Clusters:* 1963.
NICOLSON, IAIN. *Astronomy at British Universities:* 1966.
—*Interstellar Dust:* 1968.
—*Exploring the Outer Planets:* 1971.
—*Galaxies, Peculiar Galaxies, and Quasars:* 1972.
—*Stellar Evolution:* 1973.
PEEK, B. M. *The Satellites of Jupiter:* 1962.
PORTER, J. G. *Astronomy and Space Research:* 1963.
—*The Distance of the Sun:* 1964.
—*Short-Period Comets:* 1964.
RONAN, C. A. *Planetary Nebulæ:* 1964.
—*Johannes Kepler:* 1972.
SATTERTHWAITE, G. E. *Positional Astronomy:* 1971.
—*The Constitution of Jupiter:* 1973.
SISSON, G. M. *The Isaac Newton Telescope:* 1967.
SPRY, F. R. *A Run-off Observatory:* 1972.
VETTERLEIN, J. *Double and Binary Stars:* 1962.
WARNER, B. *Peculiarities among the Cool Stars:* 1965.
WAYMAN, P. A. *Spiral Structure in Galaxies:* 1968.

INDEX TO ARTICLES IN PREVIOUS *YEARBOOKS*

WILDEY, H. *Telescope Mountings:* 1964.
—*The Newtonian Flat and its Mounting:* 1972.
WRIGHT, H. N. D. *The Surface of Saturn:* 1964.

Preface

New readers will find that all the information in this *Yearbook* is given in diagrammatic or descriptive form; the positions of the planets may easily be found on the specially designed star charts, while the monthly notes describe the movements of the planets, and give details of other astronomical phenomena that may be observed from these latitudes. The reader who needs more detailed information will find *Norton's Star Atlas* (Gall and Inglis) an invaluable guide, while more precise positions of the planets and their satellites, together with predictions of occultations, meteor showers and periodic comets may be found in the *Handbook* of the British Astronomical Association. A somewhat similar publication is the *Observer's Handbook* of the Royal Astronomical Society of Canada, and readers will also find details of forthcoming events given in the American *Sky and Telescope* (which also publishes complete details of all occultations visible in North America) and in the British quarterly periodical *Astronomy and Space* (David and Charles).

Important Note

The star charts are drawn, and the notes are, in general, designed for use in latitude 52 degrees north, but may be used without alteration throughout the British Isles, and (except in the case of eclipses and occultations) in other countries of similar north latitude.

The times given on the star charts and in the Monthly Notes are generally given as local times, using the 24-hour clock, the day beginning at midnight. Ignoring small differences of longitude, this local time may be taken as Greenwich Mean Time (G.M.T.) in the British Isles, or as the appropriate Standard

Time in other Time Zones. If Summer Time is in use, the clocks will have been advanced by one hour, and this hour must be subtracted from the clock time to give G.M.T.

In Great Britain and N. Ireland, Summer Time will be in force in 1974 from 17 March 02^h to 27 October 02^h.

The times of a few events (e.g., eclipses) are given in G.M.T., and this may be converted to Local Mean Time by subtracting the west longitude (or adding the east longitude).

Local Mean Time = G.M.T. – West Longitude

Similarly,

Eastern Standard Time = G.M.T. – 5 hours,
Central Standard Time = G.M.T. – 6 hours, etc.

PART ONE

Events of 1974

Monthly Charts and Astronomical Phenomena

Notes on the Star Charts

The stars, together with the Sun, Moon and planets, seem to be set on the surface of the celestial sphere, which appears to rotate about the Earth from east to west. Since it is impossible to represent a curved surface accurately on a plane, any kind of star map is bound to contain some form of distortion. But it is well known that the eye can endure some kinds of distortion better than others, and it is particularly true that the eye is most sensitive to deviations from the vertical and horizontal. For this reason the star charts given in this volume on pages 20 to 45 have been designed to give a true representation of vertical and horizontal lines, whatever may be the resulting distortion in the shape of a constellation figure. It will be found that the amount of distortion is, in general, quite small, and is only obvious in the case of large constellations such as Leo and Pegasus, when these appear at the top of the charts, and so are drawn out sideways.

The charts show all stars down to the fourth magnitude, together with a number of fainter stars which are necessary to define the shape of a constellation. There is no standard system for representing the outlines of the constellations, and triangles and other simple figures have been used used to give outlines which are easy to follow with the naked eye. The names of the constellations are given, together with the proper names of the brighter stars. The apparent magnitude of the stars are indicated roughly by using four different sizes of dots, the larger dots representing the bright stars.

There are four such charts at each opening, and these give a complete coverage of the sky up to an altitude of 62½ degrees; there are twelve such sets to cover the entire year. The upper two charts show the southern sky, south being at the centre; the coverage is 200 degrees in azimuth, from a little north of east (top left) to a little north of west (top right). The two lower charts show the northern sky, from a little south of west (lower left) to a little south of east (lower right). There is thus an overlap east and west.

The charts have been drawn for a latitude of 52 degrees, but may be taken without appreciable error to apply to all parts of the British Isles. They will also be equally suitable for any other part of the world having a north latitude of about 52 degrees — e.g. parts of Europe and Asia, and Canada. In such cases the times given must be taken as local time, and not G.M.T., which applies only to the British Isles.

Because the sidereal day is shorter than the solar day, the stars appear to rise and set about four minutes earlier each day, which amounts to two hours in a month. Hence, the twelve sets of charts are sufficient to give the appearance of the sky throughout the day at intervals of two hours, or at the same time of night at monthly intervals throughout the year. The actual range of dates and times when the stars on the charts are visible is indicated at the top of each page. This information is summarized in the following table, which gives the number of the star chart to be used for any given month and time.

G.M.T.	16^h	18^h	20^h	22^h	0^h	2^h	4^h	6^h
January	10	11	12	1	2	3	4	5
February		12	1	2	3	4	5	6
March			2	3	4	5	6	
April			3	4	5	6		
May			4	5	6	7		
June			5	6	7			
July			6	7	8	9		
August			7	8	9	10	11	
September		7	8	9	10	11	12	
October		8	9	10	11	12	1	
November	8	9	10	11	12	1	2	3
December	9	10	11	12	1	2	3	4

The charts are drawn to scale, and estimates of altitude and azimuth may be made from them. These values will necessarily be mere approximations, since no observer will be exactly on the meridian of Greenwich at 52 degrees latitude, but they will generally serve for the identification of stars and planets. The horizontal measurements, marked at every ten degrees, give the azimuths (or true bearings) measured from the north round through east (90 degrees), south (180 degrees), and west (270 degrees). The vertical measurements, similarly marked, give the altitudes of the stars up to 62½ degrees.

The ecliptic is drawn as a broken line on which the longitude is marked at every ten degrees; the positions of the planets at any time are then easily found by reference to the table immediately following the star charts on page 46.

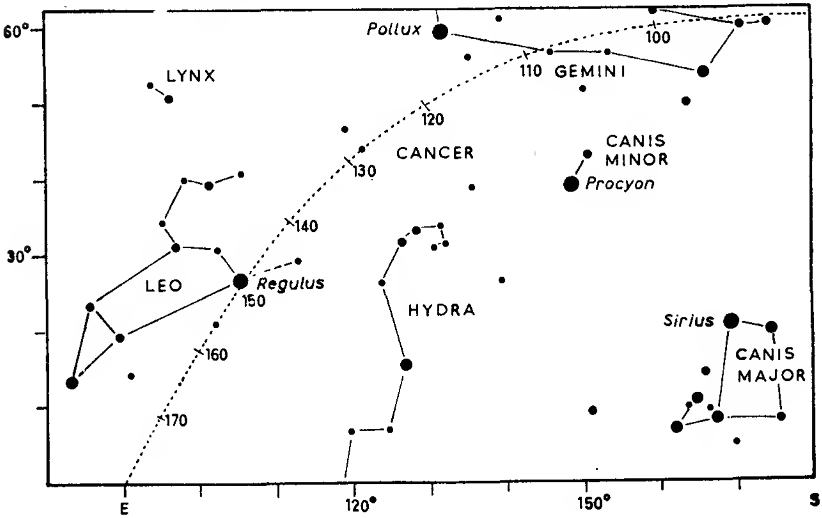
There is a curious illusion that stars at an altitude of 60 degrees or more are actually overhead, and the beginner may often feel that he is leaning over backwards in trying to see them. These high-altitude stars, being nearer the pole, move more slowly across the sky, and a different kind of map may therefore be used. These overhead stars are given separately on pages 44 and 45, the entire year being covered at one opening. Each of the four maps shows the overhead stars at times which correspond to those of three of the main star charts. The position of the zenith in latitude 52 degrees is indicated by a cross, and this cross also marks the centre of a circle which is 35 degrees from the zenith, and which therefore indicates an altitude of 55 degrees; there is thus a small overlap with the main charts.

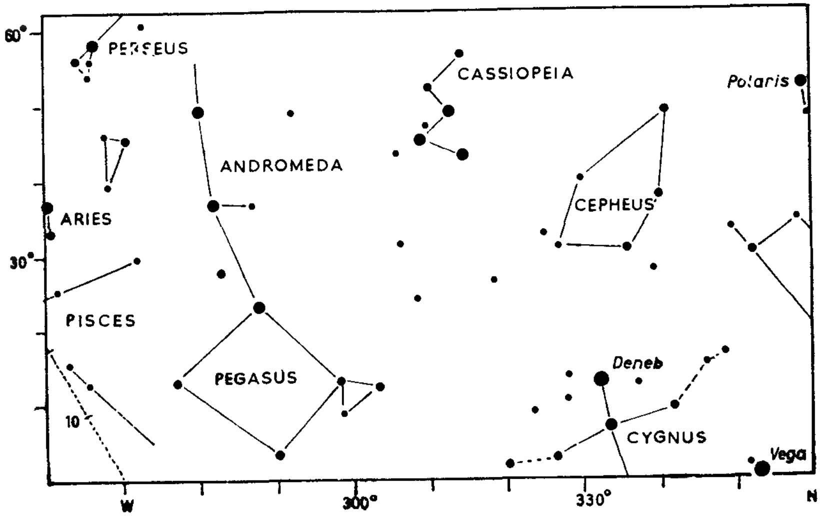
The broken line leading from north to south is numbered to indicate the corresponding main chart. Thus on page 44 the N–S line numbered 6 is to be regarded as an extension of the S line of chart 6 on pages 30 and 31, and at the top of these pages are given dates and times which are appropriate.

The scale is the same on all the charts (approximately 25 degrees to the inch), but the overhead stars are plotted as a true map on a conical projection, and are not simple graphs like the main charts.

1L

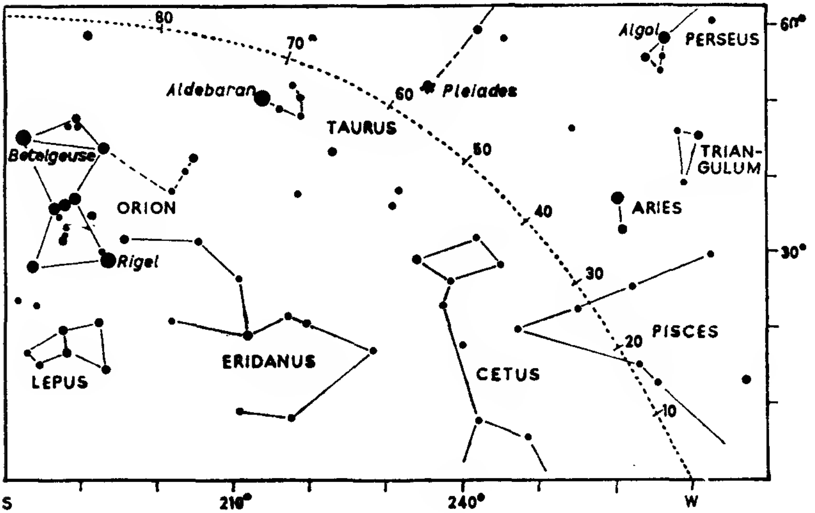
October 6 at 5^h October 21 at 4^h
November 6 at 3^h November 21 at 2^h
December 6 at 1^h December 21 at midnight
January 6 at 23^h January 21 at 22^h
February 6 at 21^h February 21 at 20^h

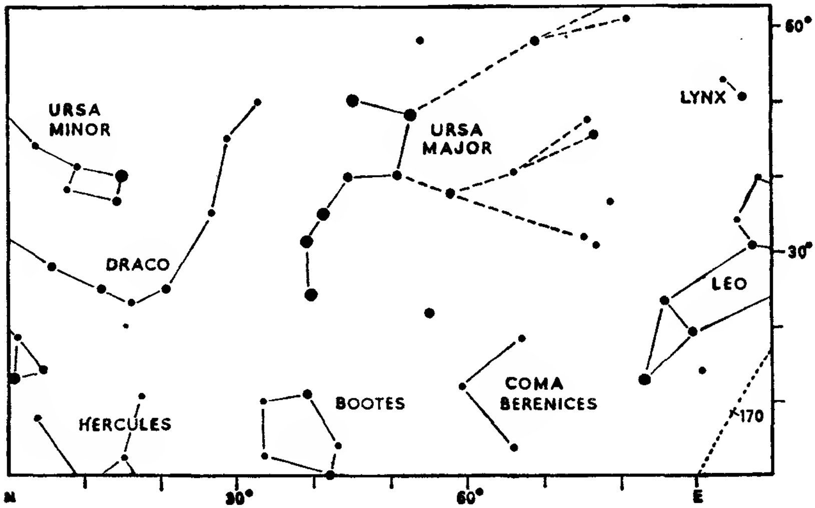




October 6 at 5^h	October 21 at 4^h
November 6 at 3^h	November 21 at 2^h
December 6 at 1^h	December 21 at midnight
January 6 at 23^h	January 21 at 22^h
February 6 at 21^h	February 21 at 20^h

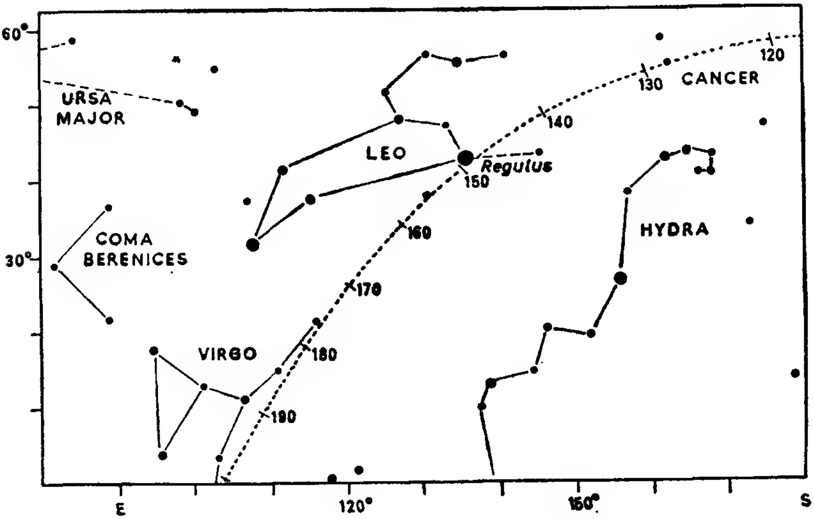
1R

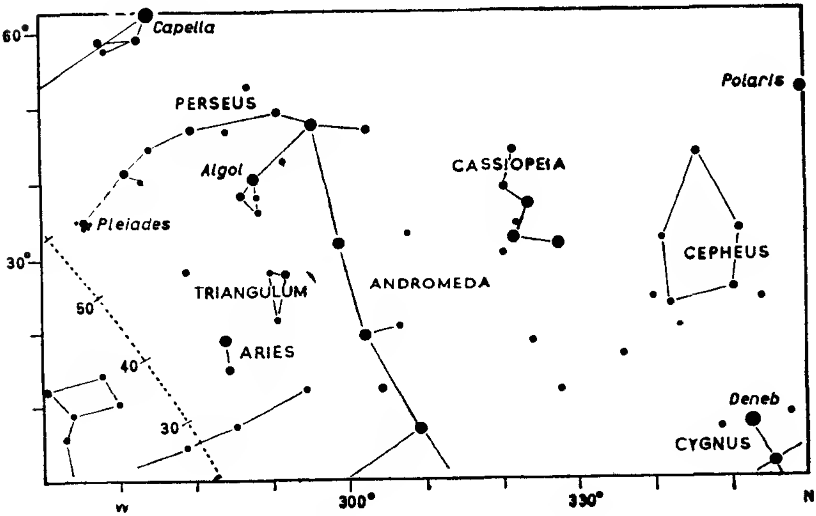




2L

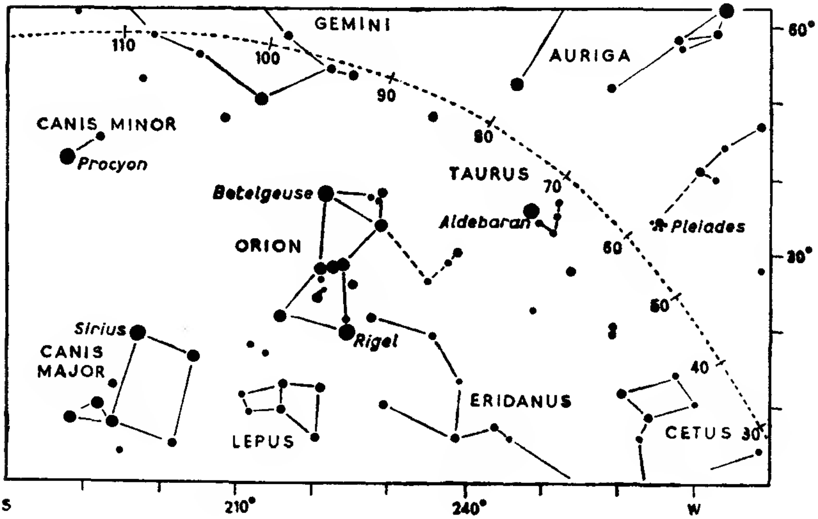
November 6 at 5^{h}	November 21 at 4^{h}
December 6 at 3^{h}	December 21 at 2^{h}
January 6 at 1^{h}	January 21 at midnight
February 6 at 23^{h}	February 21 at 22^{h}
March 6 at 21^{h}	March 21 at 20^{h}

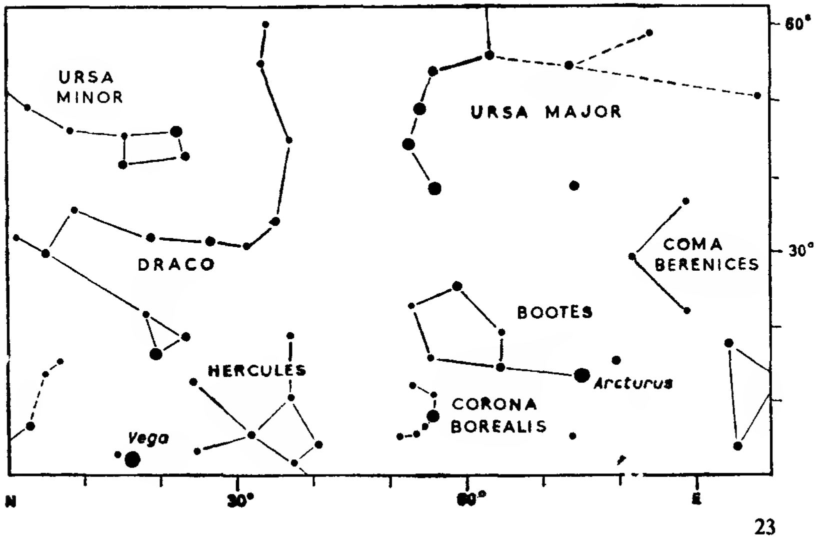




November 6 at	5^h	November 21 at	4^h
December 6 at	3^h	December 21 at	2^h
January 6 at	1^h	January 21 at	midnight
February 6 at	23^h	February 21 at	22^h
March 6 at	21^h	March 21 at	20^h

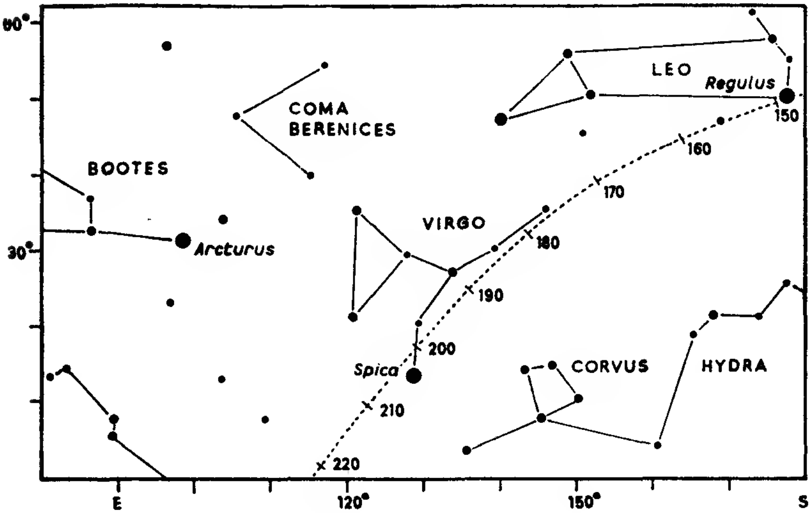
2R

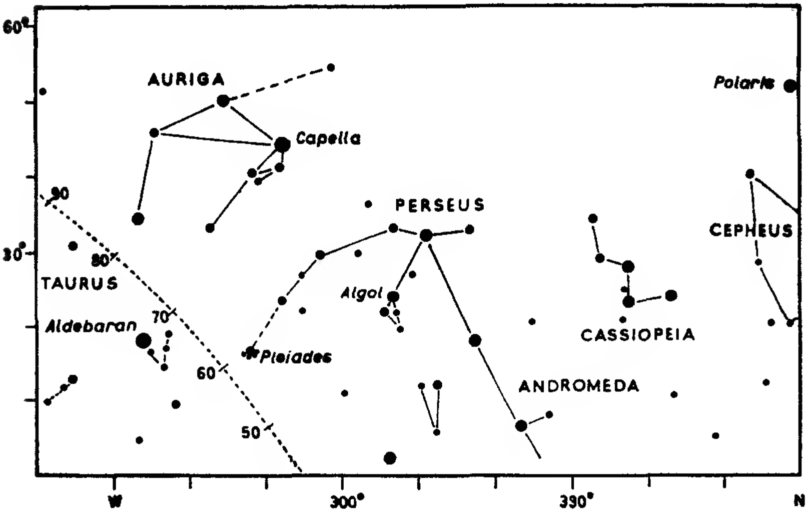




3L

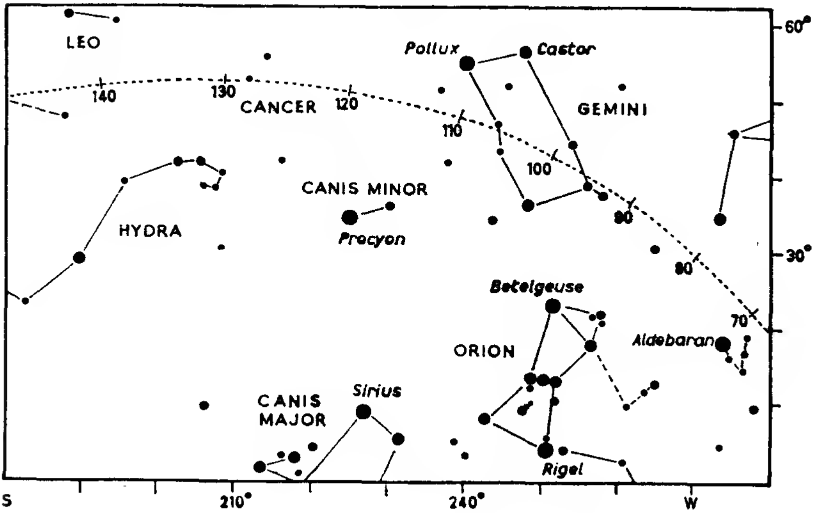
December 6 at 5^h	December 21 at 4^h
January 6 at 3^h	January 21 at 2^h
February 6 at 1^h	February 21 at midnight
March 6 at 23^h	March 21 at 22^h
April 6 at 21^h	April 21 at 20^h

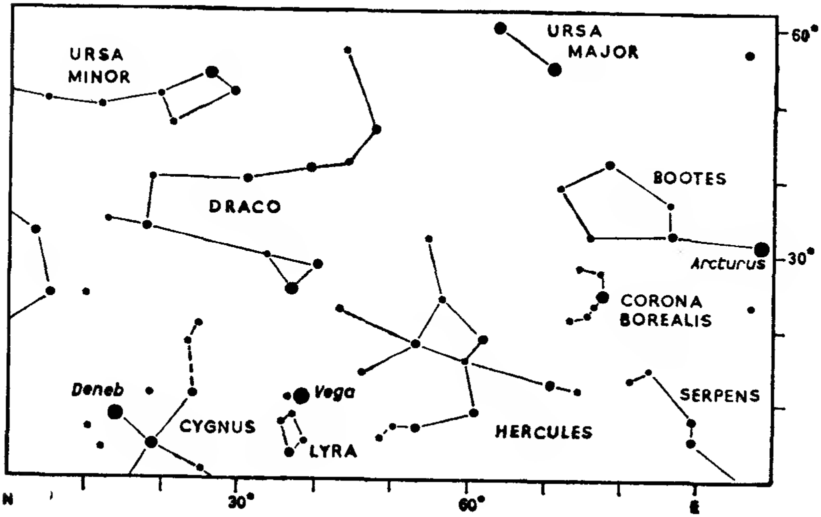




December 6 at 5^{h} December 21 at 4^{h}
January 6 at 3^{h} January 21 at 2^{h}
February 6 at 1^{h} February 21 at midnight
March 6 at 23^{h} March 21 at 22^{h}
April 6 at 21^{h} April 21 at 20^{h}

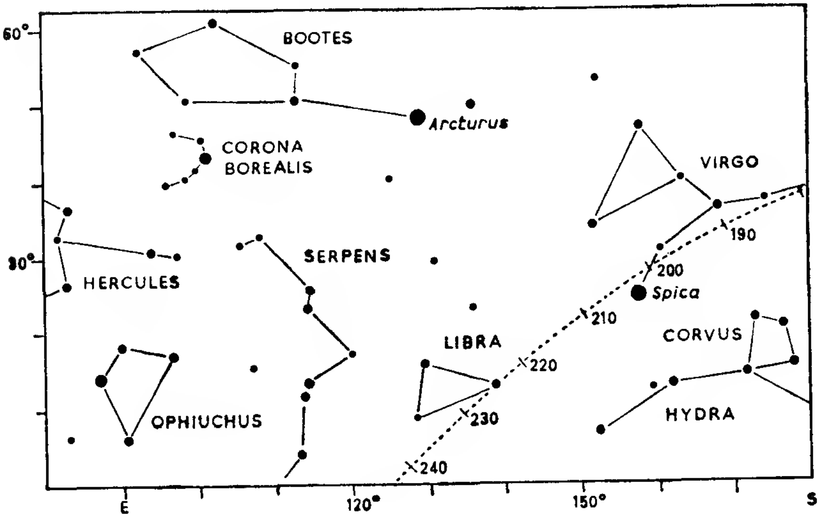
3R

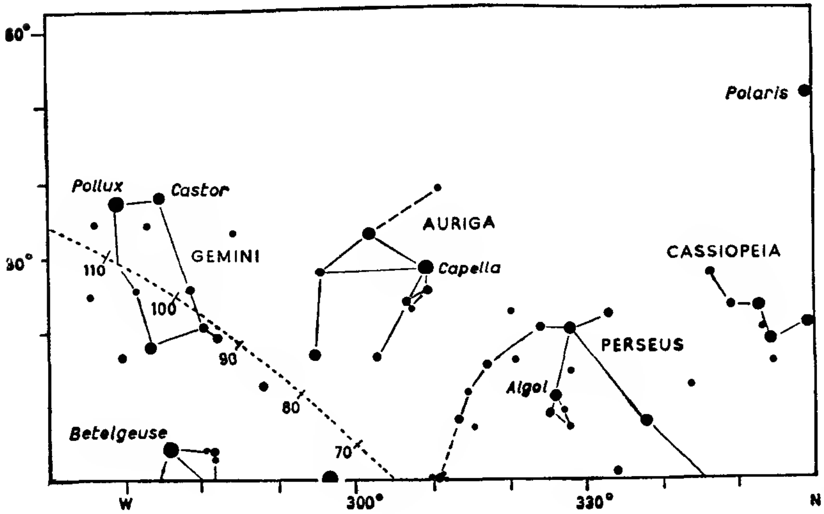




4L

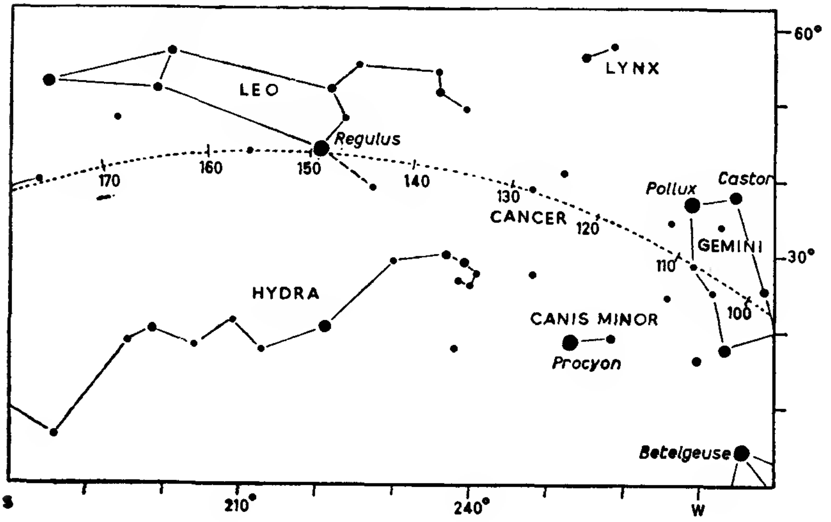
January 6 at 5h	January 21 at 4h
February 6 at 3h	February 21 at 2h
March 6 at 1h	March 21 at midnight
April 6 at 23h	April 21 at 22h
May 6 at 21h	May 21 at 20h

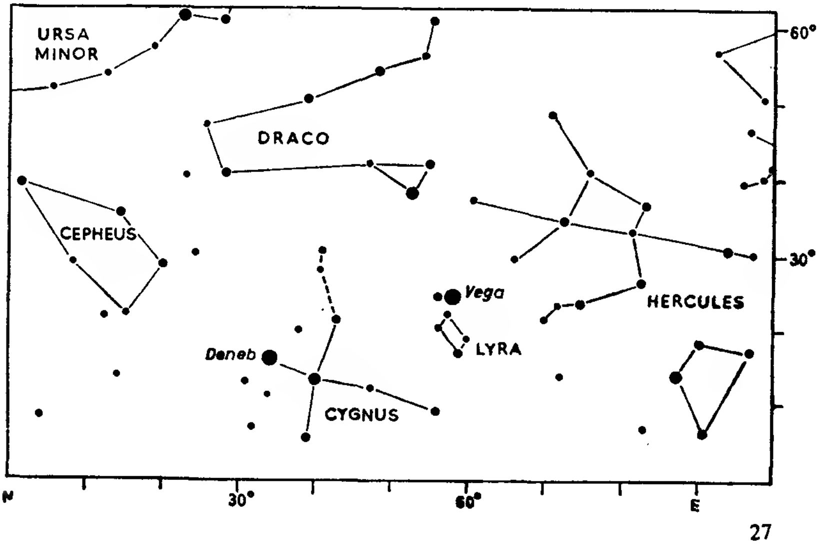




January 6 at 5^h	January 21 at 4^h
February 6 at 3^h	February 21 at 2^h
March 6 at 1^h	March 21 at midnight
April 6 at 23^h	April 21 at 22^h
May 6 at 21^h	May 21 at 20^h

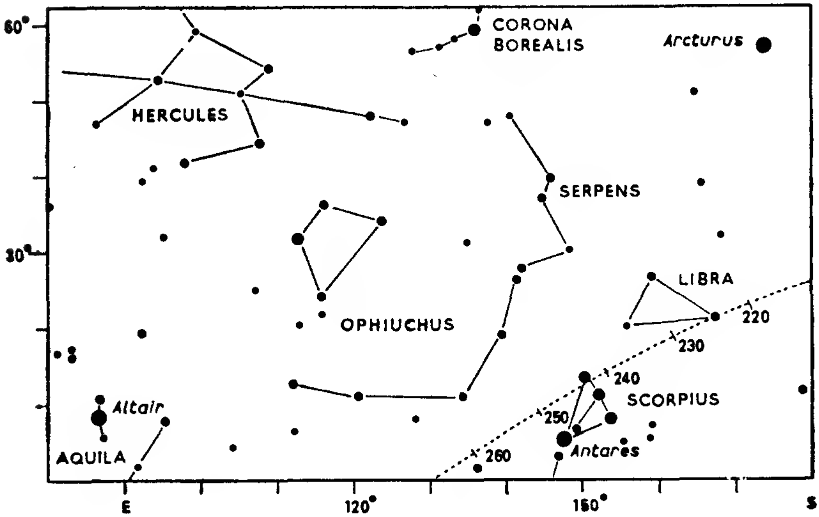
4R

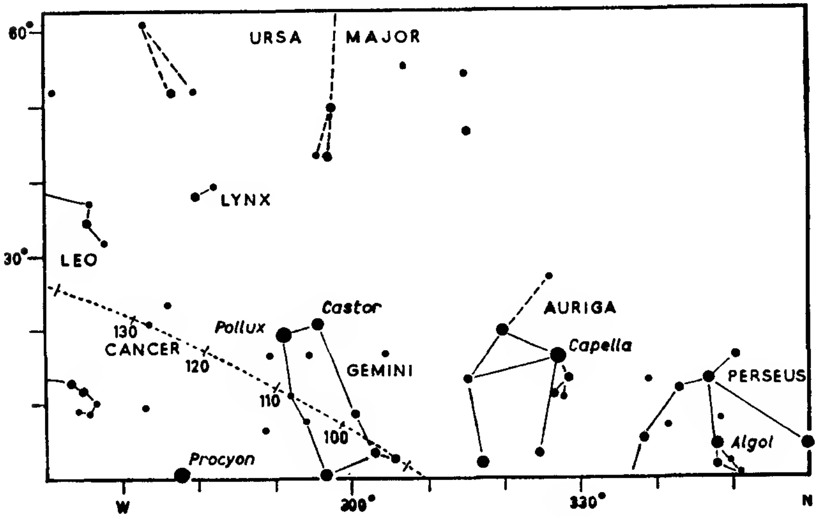




5L

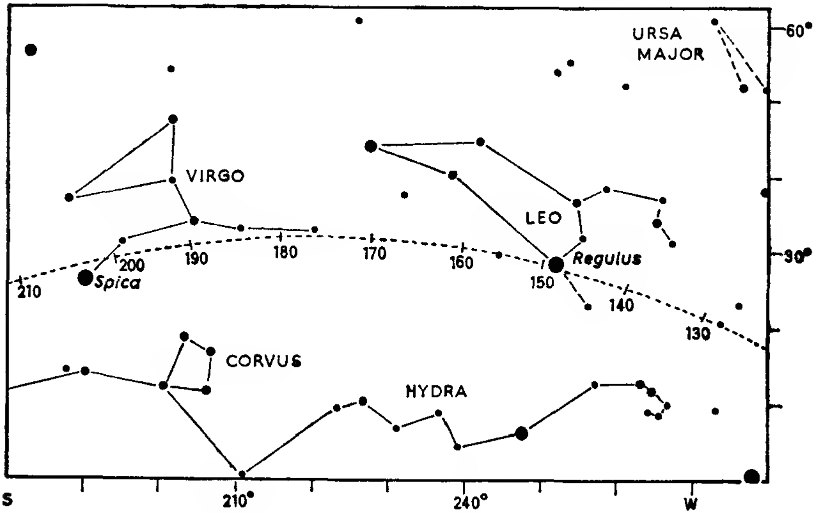
January 6 at	7^h	January 21 at	6^h
February 6 at	5^h	February 21 at	4^h
March 6 at	3^h	March 21 at	2^h
April 6 at	1^h	April 21 at	midnight
May 6 at	23^h	May 21 at	22^h

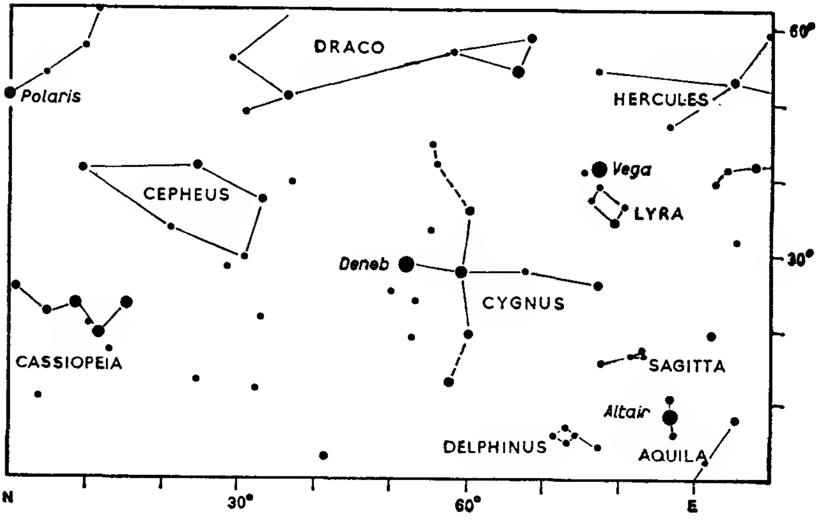




January 6 at 7^h	January 21 at 6^h
February 6 at 5^h	February 21 at 4^h
March 6 at 3^h	March 21 at 2^h
April 6 at 1^h	April 21 at midnight
May 6 at 23^h	May 21 at 22^h

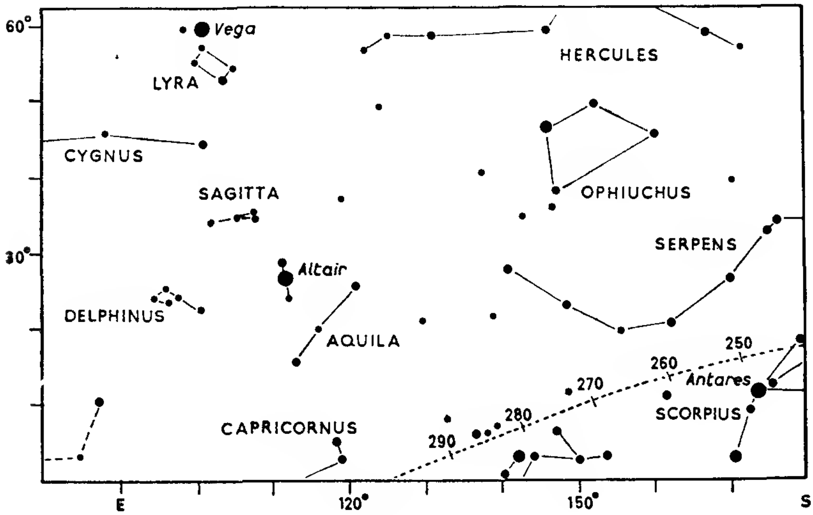
5R

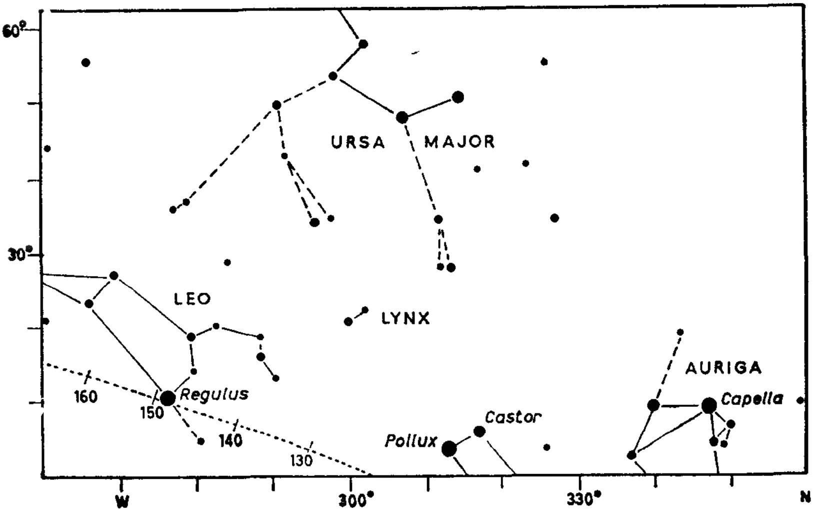




6L

March 6 at 5h	March 21 at 4h
April 6 at 3h	April 21 at 2h
May 6 at 1h	May 21 at midnight
June 6 at 23h	June 21 at 22h
July 6 at 21h	July 21 at 20h





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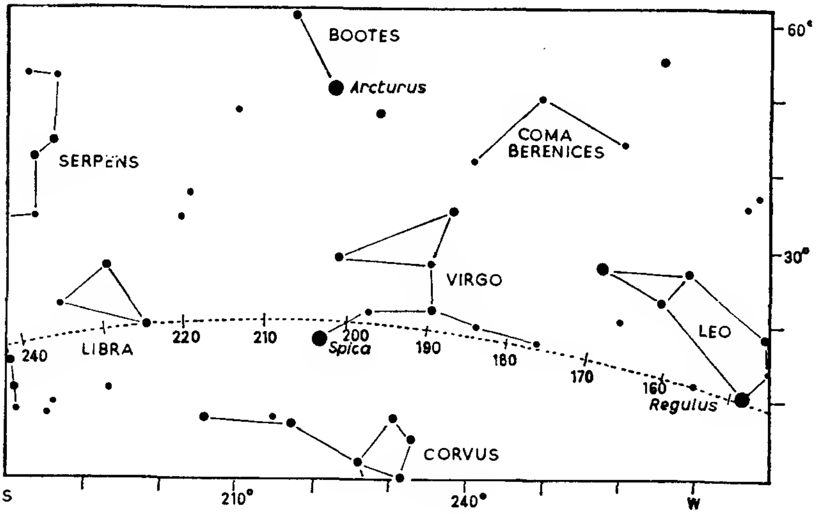
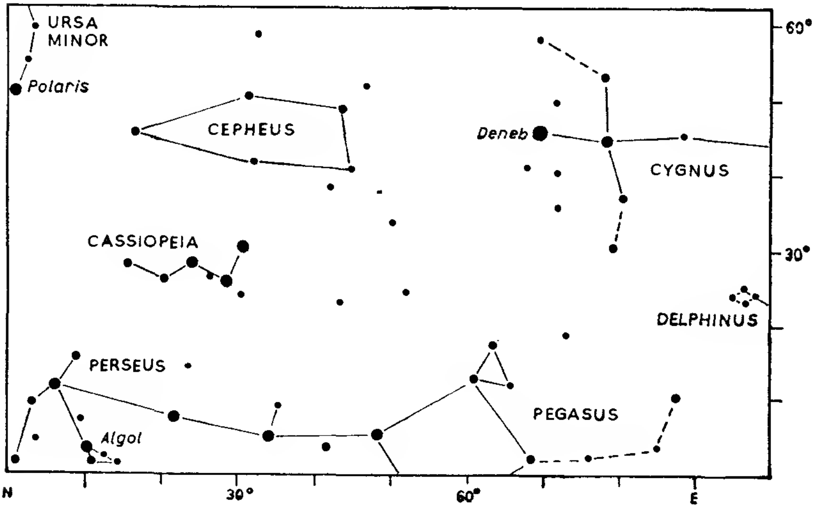
April 6 at 3^h	April 21 at 2^h
May 6 at 1^h	May 21 at midnight
June 6 at 23^h	June 21 at 22^h
July 6 at 21^h	July 21 at 20^h

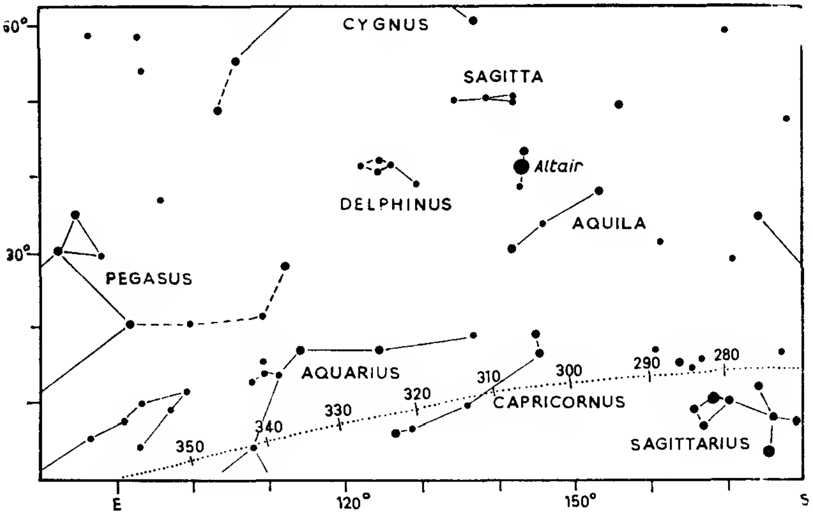
6R

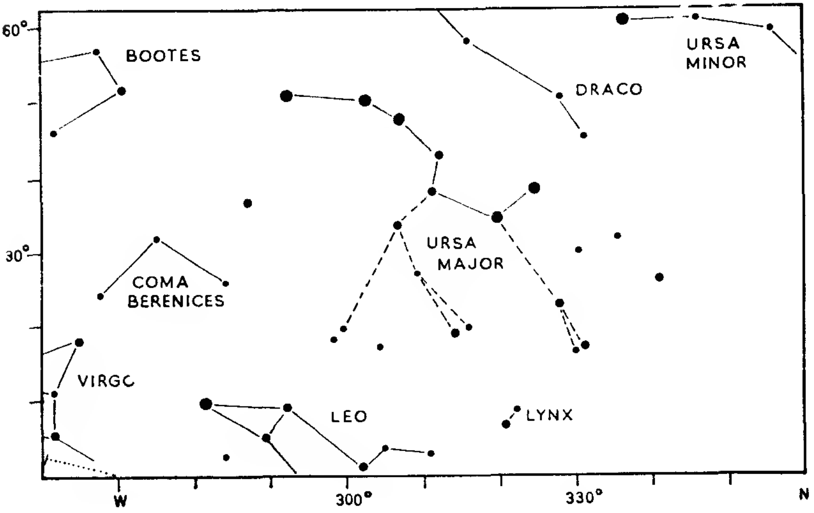




7L

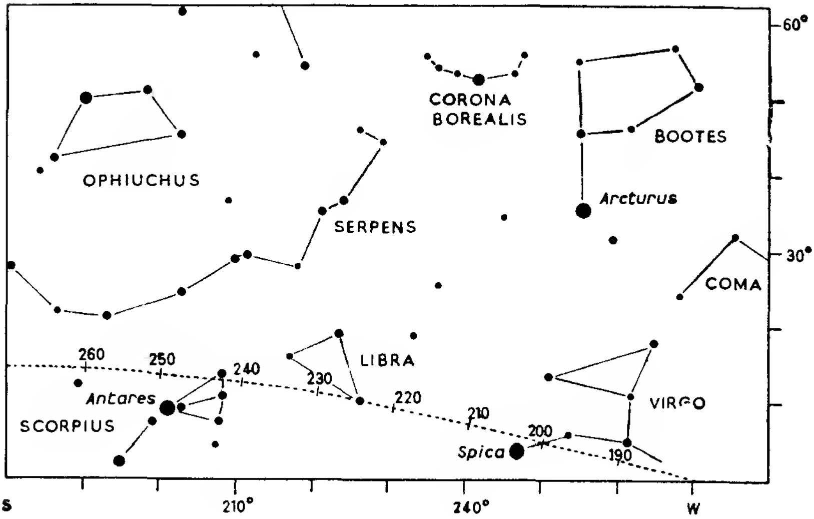
May 6 at 3h	May 21 at 2h
June 6 at 1h	June 21 at midnight
July 6 at 23h	July 21 at 22h
August 6 at 21h	August 21 at 20h
September 6 at 19h	September 21 at 18h

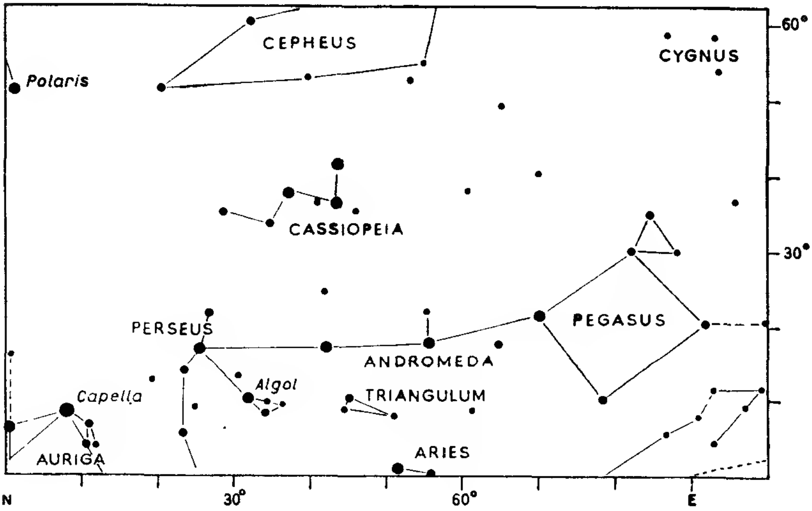




May 6 at 3^{h}	May 21 at 2^{h}
June 6 at 1^{h}	June 21 at midnight
July 6 at 23^{h}	July 21 at 22^{h}
August 6 at 21^{h}	August 21 at 20^{h}
September 6 at 19^{h}	September 21 at 18^{h}

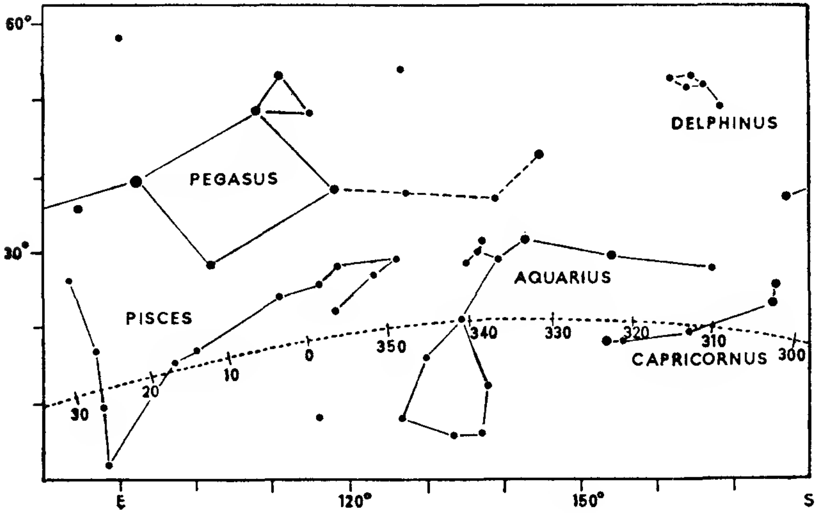
7R

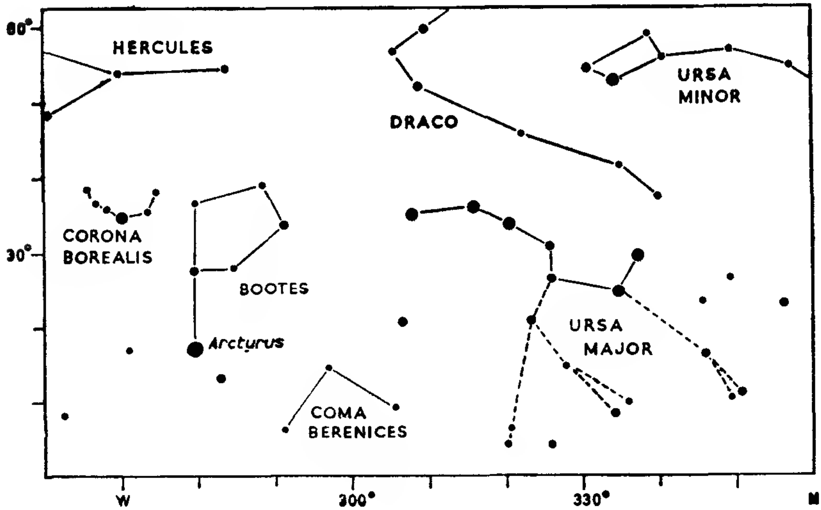




8L

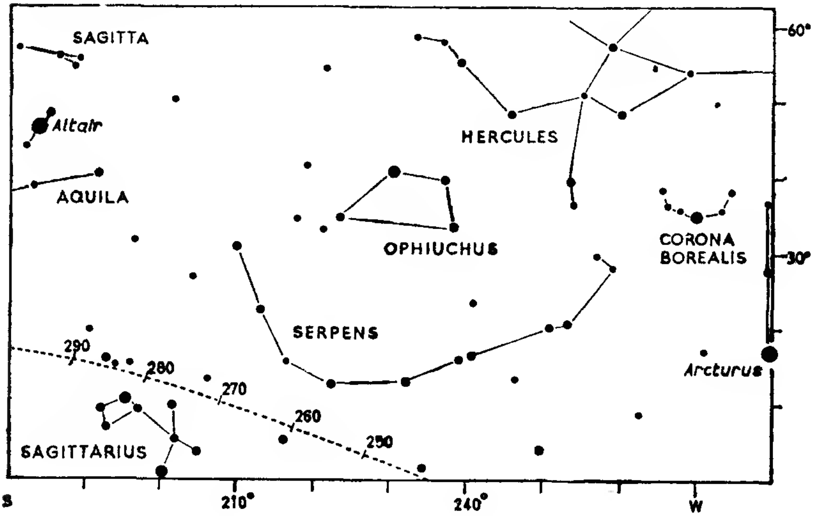
July 6 at 1^h	July 21 at midnight
August 6 at 23^h	August 21 at 22^h
September 6 at 21^h	September 21 at 20^h
October 6 at 19^h	October 21 at 18^h
November 6 at 17^h	November 21 at 16^h

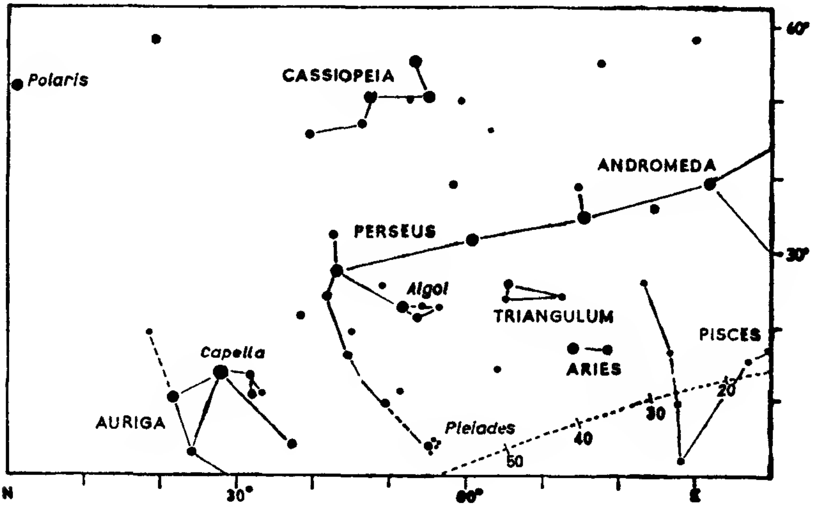




July 6 at 1^h	July 21 at midnight
August 6 at 23^h	August 21 at 22^h
September 6 at 21^h	September 21 at 20^h
October 6 at 19^h	October 21 at 18^h
November 6 at 17^h	November 21 at 16^h

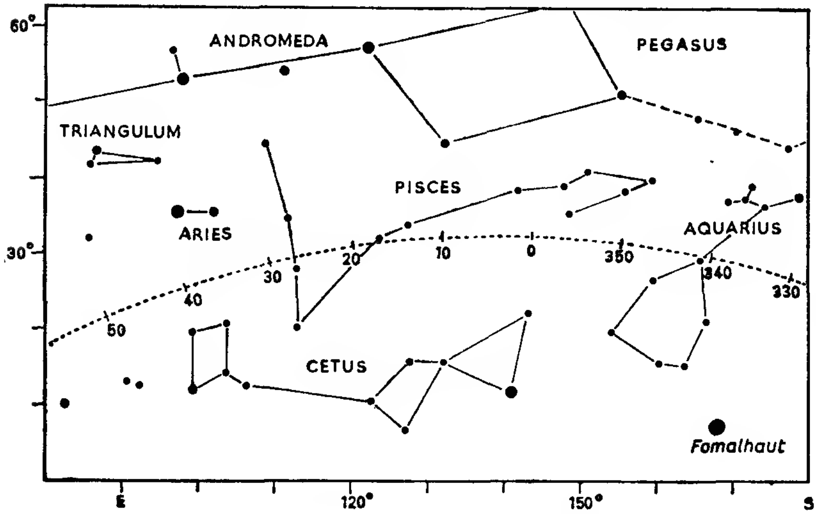
8R

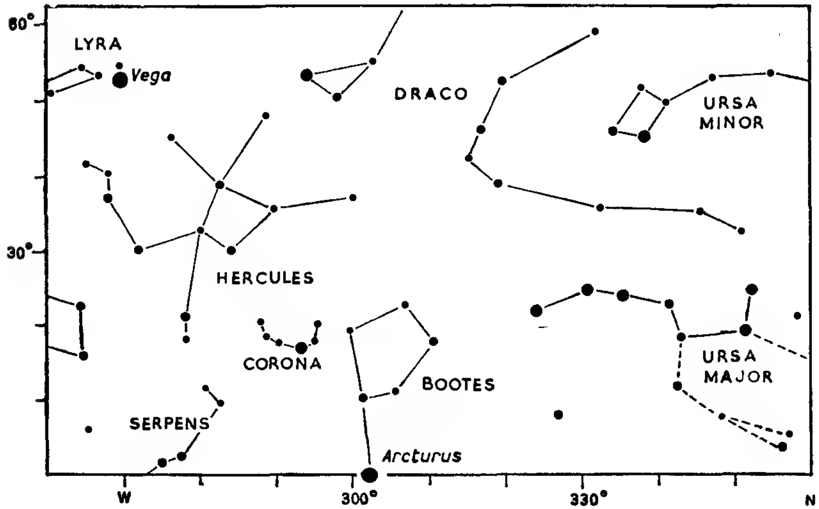




9L

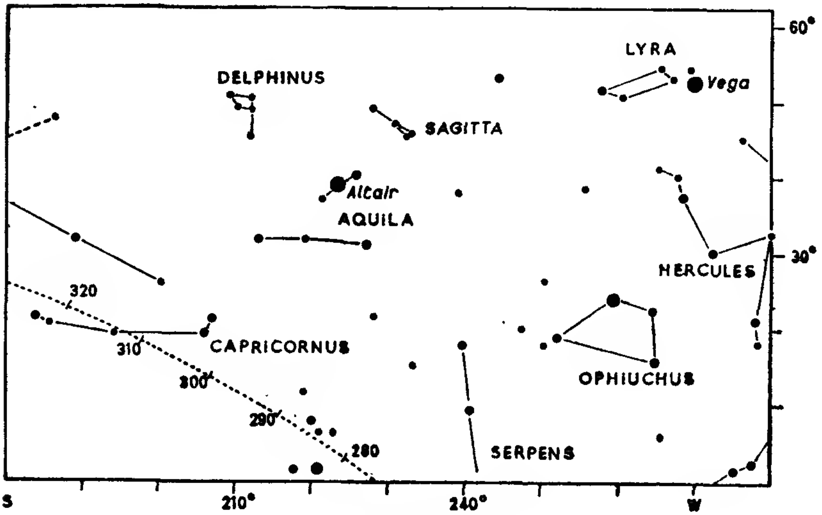
August 6 at 1^h	August 21 at midnight
September 6 at 23^h	September 21 at 22^h
October 6 at 21^h	October 21 at 20^h
November 6 at 19^h	November 21 at 18^h
December 6 at 17^h	December 21 at 16^h

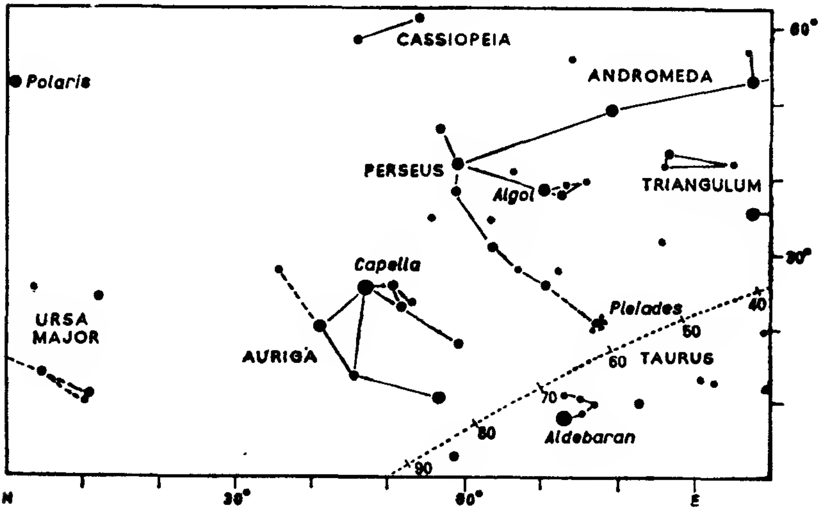




August 6 at 1^{h}	August 21 at midnight
September 6 at 23^{h}	September 21 at 22^{h}
October 6 at 21^{h}	October 21 at 20^{h}
November 6 at 19^{h}	November 21 at 18^{h}
December 6 at 17^{h}	December 21 at 16^{h}

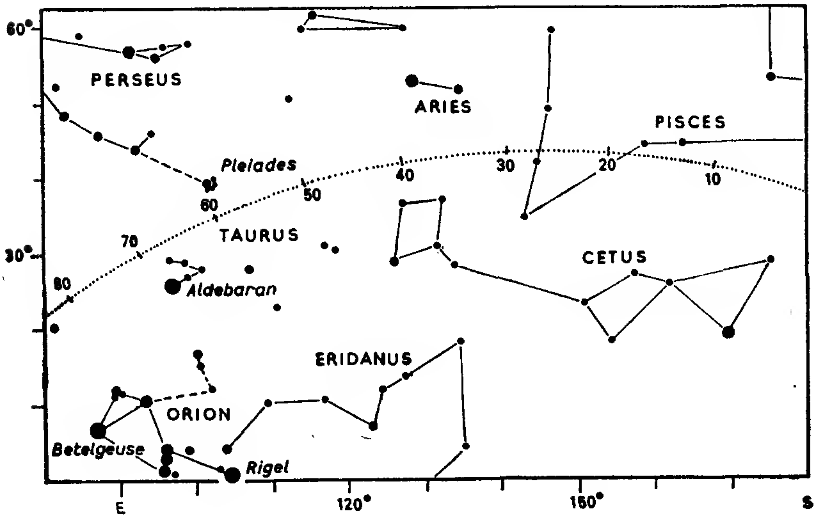
9R

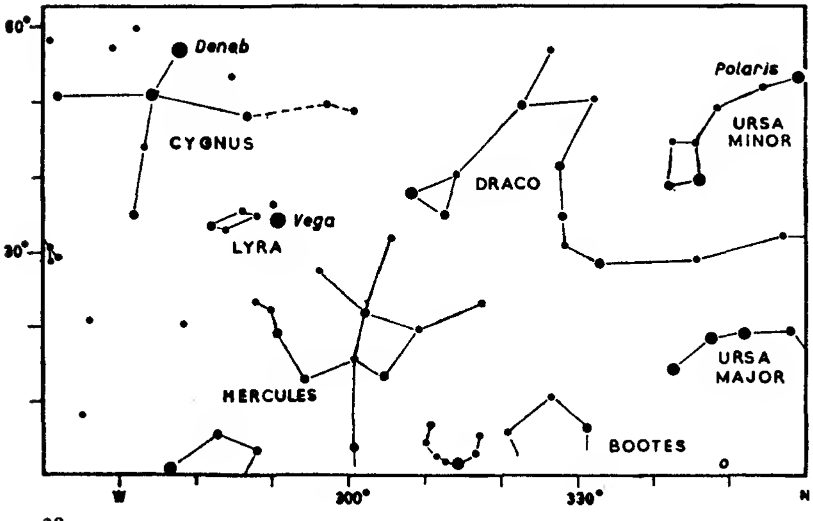




10L

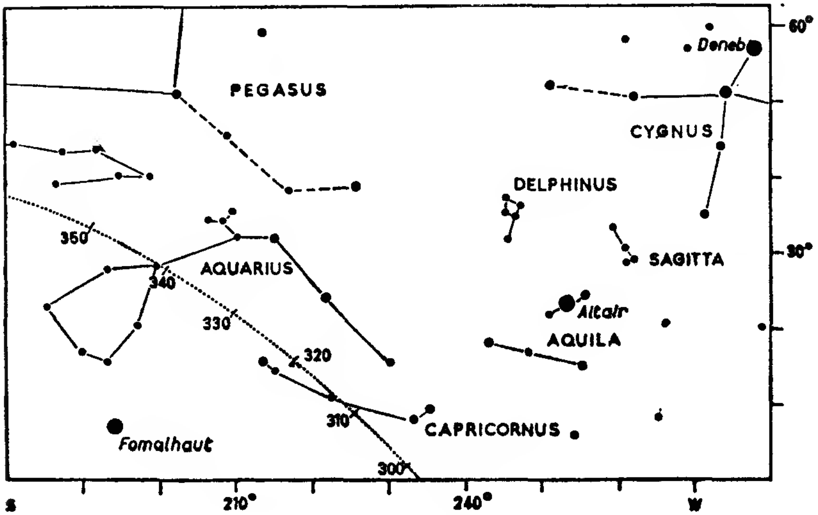
August 6 at 3h	August 21 at 2h
September 6 at 1h	September 21 at midnight
October 6 at 23h	October 21 at 22h
November 6 at 21h	November 21 at 20h
December 6 at 19h	December 21 at 18h

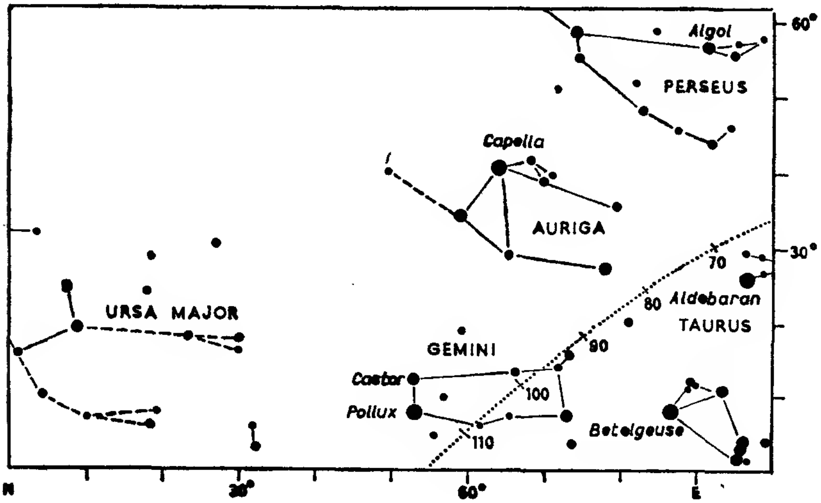




August 6 at 3^{h}	August 21 at 2^{h}
September 6 at 1^{h}	September 21 at midnight
October 6 at 23^{h}	October 21 at 22^{h}
November 6 at 21^{h}	November 21 at 20^{h}
December 6 at 19^{h}	December 21 at 18^{h}

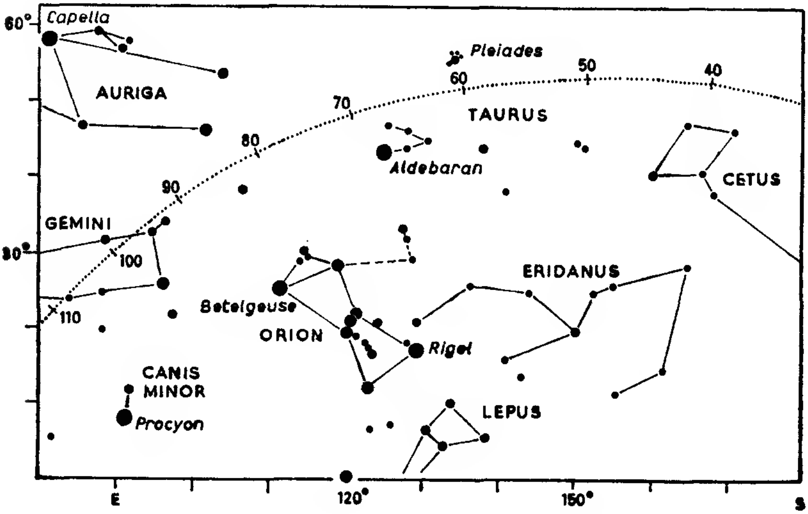
10R

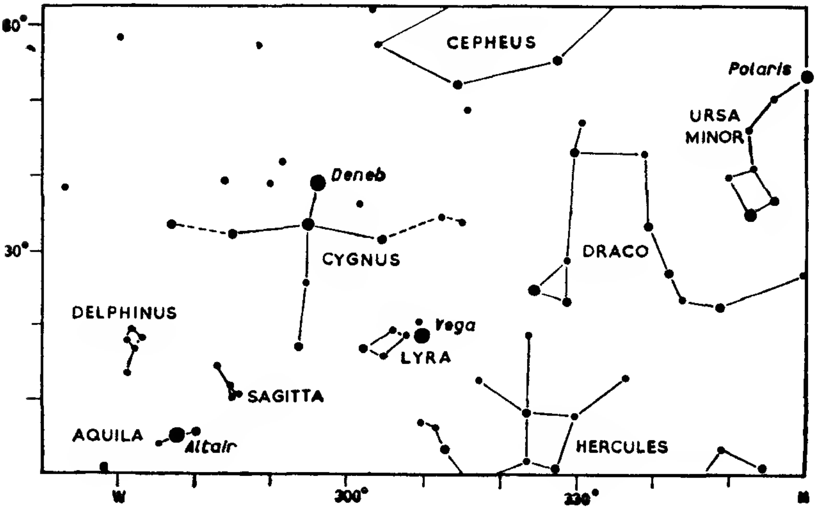




11L

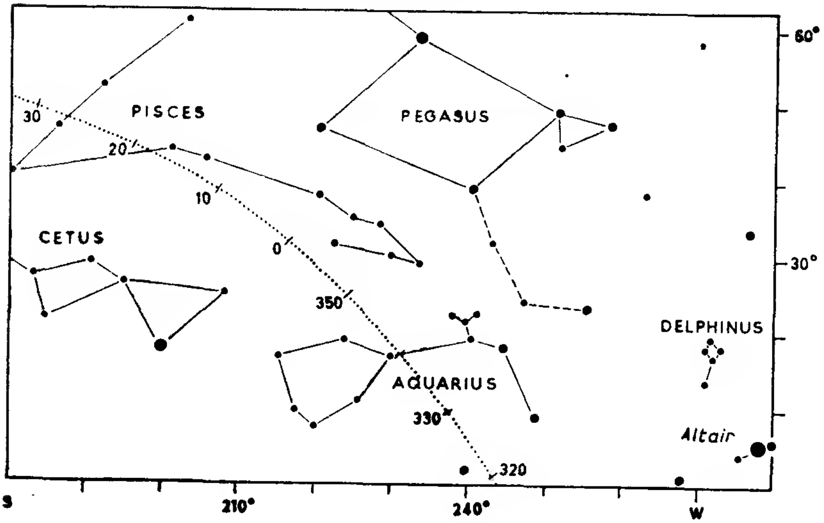
September	6	at	3h	September	21	at	2h
October	6	at	1h	October	21	at	midnight
November	6	at	23h	November	21	at	22h
December	6	at	21h	December	21	at	20h
January	6	at	19h	January	21	at	18h

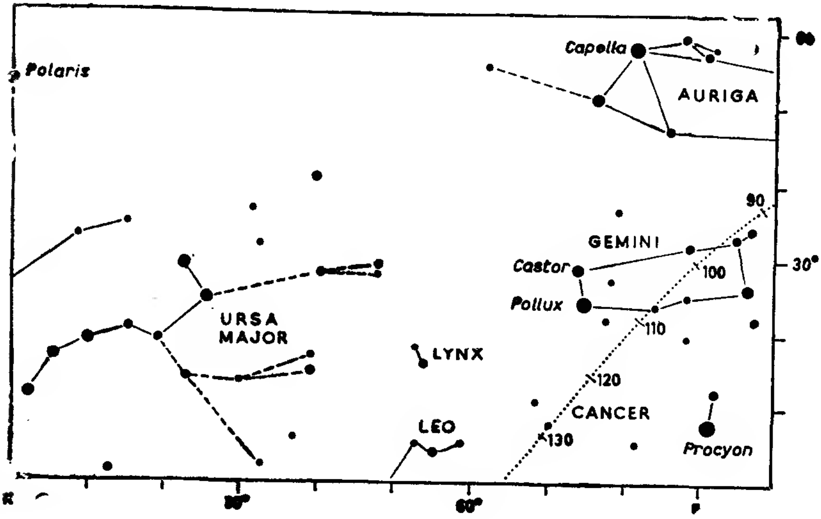




September 6 at 3^{h}	September 21 at 2^{h}
October 6 at 1^{h}	October 21 at midnight
November 6 at 23^{h}	November 21 at 22^{h}
December 6 at 21^{h}	December 21 at 20^{h}
January 6 at 19^{h}	January 21 at 18^{h}

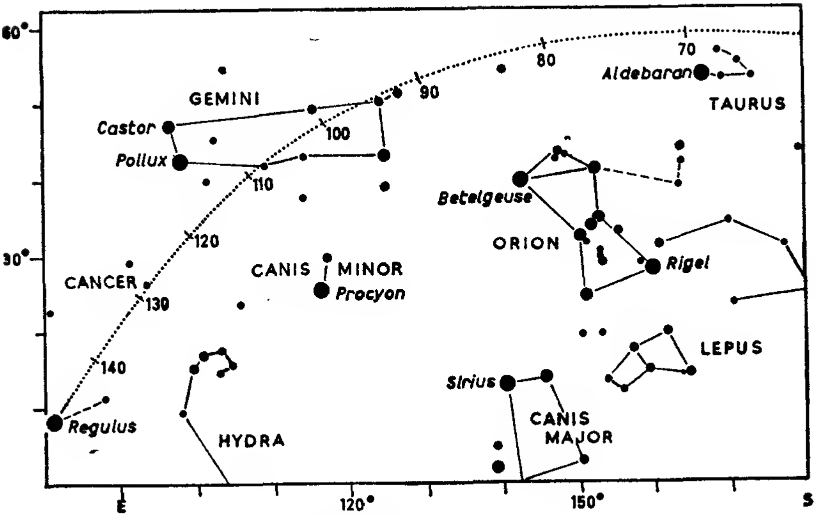
11R

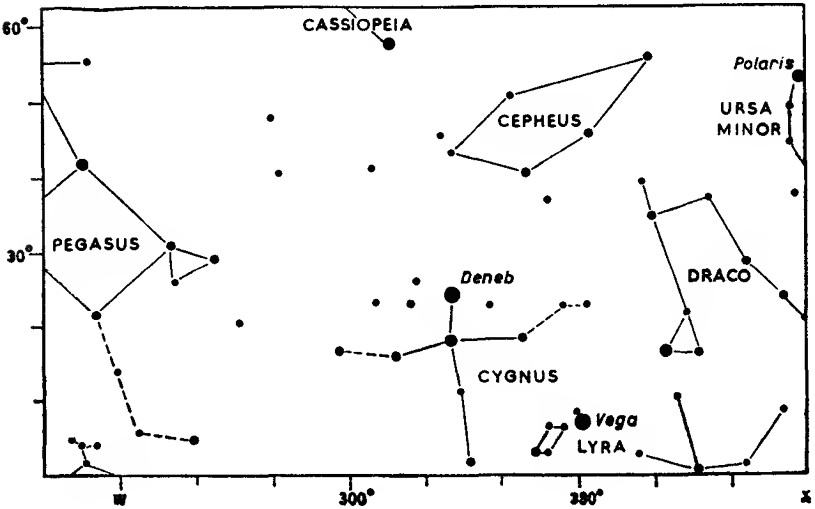




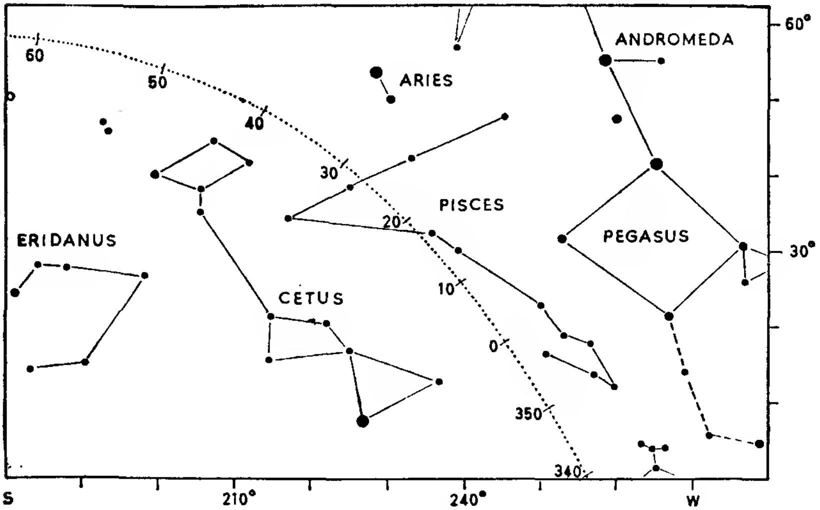
12L

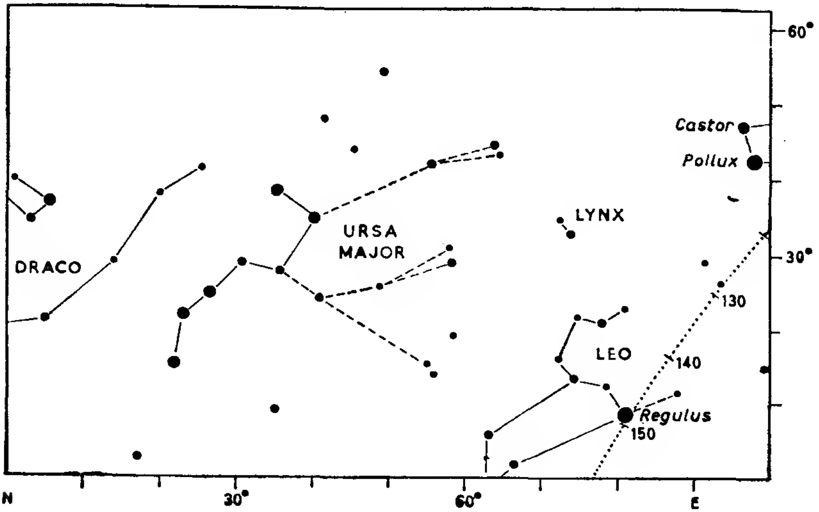
October	6	at	3^h	October	21	at	2^h
November	6	at	1^h	November	21	at	midnight
December	6	at	23^h	December	21	at	22^h
January	6	at	21^h	January	21	at	20^h
February	6	at	19^h	February	21	at	18^h

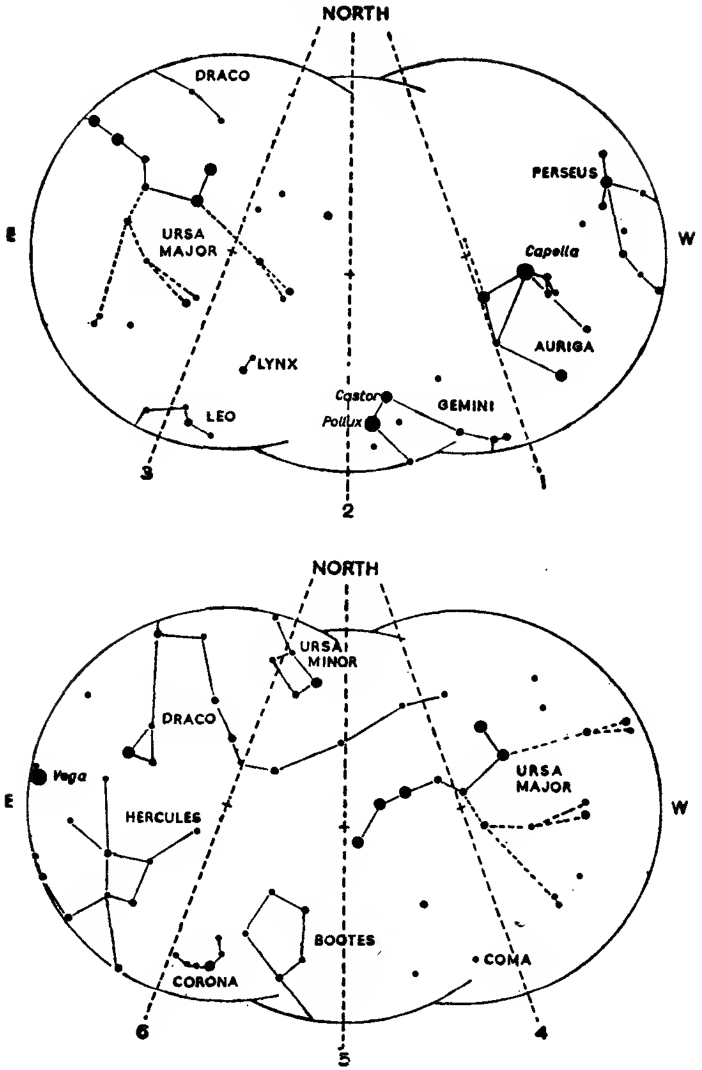




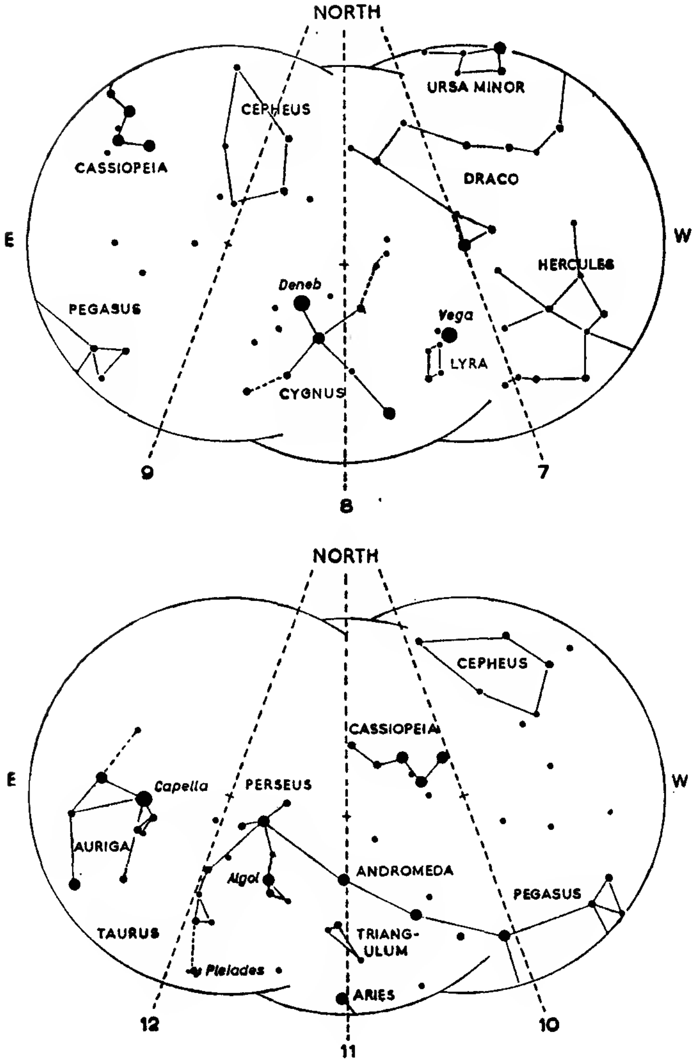
October 6 at 3^h	October 21 at 2^h	
November 6 at 1^h	November 21 at midnight	
December 6 at 23^h	December 21 at 22^h	**12R**
January 6 at 21^h	January 21 at 20^h	
February 6 at 19^h	February 21 at 18^h	







Overhead stars



Overhead stars

The Planets in 1974

DATE		*Venus*	*Mars*	*Jupiter*	*Saturn*	*Uranus*	*Neptune*
January	6	310°	34°	316°	90°	208°	249°
	21	304	40	319	89	208	249
February	6	295	48	323	88	208	250
	21	296	56	327	88	208	250
March	6	302	63	330	88	208	250
	21	314	72	333	88	207	250
April	6	329	81	337	89	206	250
	21	345	90	340	90	206	249
May	6	2	99	343	92	205	249
	21	19	109	345	93	205	249
June	6	37	118	347	95	204	248
	21	55	128	348	97	204	248
July	6	72	137	348	99	204	248
	21	90	146	348	101	204	247
August	6	109	156	347	103	204	247
	21	127	166	346	105	205	247
September	6	147	176	344	106	206	247
	21	166	186	342	107	206	247
October	6	185	195	340	108	207	248
	21	203	205	339	109	208	248
November	6	223	216	339	109	209	249
	21	242	226	339	108	210	249
December	6	261	237	340	108	211	250
	21	280	247	342	107	212	250
Conjunction:							
Inferior		Jan. 23	—	—	—	—	—
Superior		Nov. 6	Oct. 14	Feb. 13	June 30	Oct. 21	Dec. 1
Opposition:		—	—	Sept. 5	—	Apr. 16	May 30

Mercury moves so quickly among the stars that it is not possible to indicate its position on the star charts at a convenient interval. The monthly notes must be consulted for the best times at which the planet may be seen.

The positions of the other planets are given in the table on the opposite page. This gives the apparent longitudes on dates which correspond to those of the star charts, and the position of the planet may at once be found near the ecliptic at the given longitude.

Examples:

(1) *What is the bright planet rising in the east at midnight in late June?*
Star chart 7L shows the stars in the east at this time, and the longitude of the planet is seen to be about 350°. From the table opposite it may be seen that the only planet in this region of the sky at the time is Jupiter.

(2) *Where may Mars be found at the end of February?*
The table opposite shows the longitude of Mars to be about 60° at the end of February. Star charts 2R and 3L contain the ecliptic at this longitude, and show that Mars will be setting in the west at midnight and will be seen a few degrees south of the Pleiades. The monthly notes indicate that the planet is still quite bright.

The Planets and the Ecliptic

The paths of the planets about the Sun all lie close to the plane of the ecliptic, which is marked for us in the sky by the apparent path of the Sun among the stars, and is shown on the star charts by a broken line. The Moon and planets will always be found close to this line, never departing from it by more than about 7 degrees. Thus the planets are most favourably placed for observation when the ecliptic is well displayed, and this means that it should be as high in the sky as possible. This avoids the difficulty of finding a clear horizon, and also overcomes the problem of atmospheric absorption, which greatly reduces the light of the stars. Thus a star at an altitude of 10 degrees suffers a loss of 60 per cent of its light, which corresponds to a whole magnitude; at an altitude of only 4 degrees, the loss may amount to two magnitudes.

The position of the ecliptic in the sky is therefore of great importance, and since it is tilted at about 23½ degrees to the equator, it is only at certain times of the day or year that it is displayed to the best advantage. It will be realized that the Sun (and therefore the ecliptic) is at its highest in the sky at noon in midsummer, and at its lowest at noon in midwinter. Allowing for the daily motion of the sky, these times lead to the fact that the ecliptic is highest at midnight in winter, at sunset in the spring, at noon in summer and at sunrise in the autumn. Hence these are the best times to see the planets. Thus, if Venus is an evening star, in the western sky after sunset, it will be seen to best advantage if this occurs in the spring, when the ecliptic is high in the sky and slopes down steeply to the north-west. This means that the planet is not only higher in the sky, but will remain for a much longer period above the horizon. For similar reasons, a morning star will be seen at its best on autumn mornings before sunrise, when the ecliptic is high in the east. The outer planets, which can come to opposition and are then in the south at midnight, are best seen when opposition occurs in the winter months. Clearly the summer is the least favourable time to observe the planets, for the ecliptic is always low in the sky on summer nights.

Notes on the Planets in the monthly diagrams

The following general notes on observing the planets are followed by detailed month-by-month accounts of the behaviour of the planets, and of other interesting phenomena. These monthly notes include diagrams of the apparent movements of the planets at favourable times of the year. Additional notes on other astronomical phenomena will be found on the following pages.

The inferior planets, Mercury and Venus, move in smaller orbits than that of the Earth, and so are always seen near the Sun. They are most obvious at the times of greatest angular distance from the Sun (greatest elongation), which may reach 28 degrees for Mercury, or 47 degrees for Venus. They are then seen as evening stars in the western sky after sunset (at eastern elongations) or as morning stars in the eastern sky before sunrise (at western elongations). The succession of phenomena, conjunctions and elongations, always follows the same order, but the intervals between them are not equal. Thus, if either planet is moving round the far side of its orbit its motion will be to the east, in the same direction in which the Sun appears to be moving. It therefore takes much longer for the planet to overtake the Sun – that is, to come to superior conjunction – than it does when moving round to inferior conjunction, between Sun and Earth. The intervals given in the following table are average values; they remain fairly constant in the case of Venus, which travels in an almost circular orbit. In the case of Mercury, however, conditions vary widely because of the great eccentricity and inclination of the planet's orbit.

		Mercury	*Venus*
Inferior conj.	to Elongation West	22 days	72 days
Elongation West	to Superior conj.	36 days	220 days
Superior conj.	to Elongation East	36 days	220 days
Elongation East	to Inferior conj.	22 days	72 days

The greatest brilliancy of Venus always occurs about a month *before* greatest western elongation (as a morning star), or a month *after* greatest eastern elongation (as an evening star). No such rule can be given for Mercury, because its distance from Sun and Earth can vary over a wide range.

Mercury is not likely to be seen unless a clear horizon is available; it is seldom seen as much as 10 degrees above the horizon in the twilight sky. In general, it may be said that the most favourable times for seeing Mercury as an evening star will be in spring, some days before greatest eastern elongation; in autumn it may be seen as a morning star some days after greatest western elongation.

Venus is the brightest of the planets, and may be seen on occasions in broad daylight. Like Mercury, it is alternately a morning and an evening star, and will be highest in the sky when it is a morning star in autumn, or an evening star in spring. Venus is seen to best advantage when it comes to greatest eastern elongation in June; it is then well north of the Sun in the spring months and is a brilliant object in the sunset sky over a long period.

The superior planets, which travel in orbits larger than that of the Earth, differ from Mercury and Venus in that they can be seen opposite the Sun in the sky. The superior planets are morning stars after conjunction with the Sun, rising earlier each day until they come to opposition. They will then be in the south at midnight, and visible all night. After opposition, they are evening stars, setting earlier each evening until they set in the west with the Sun at the next conjunction. The interval between conjunctions or between oppositions is greatest for Mars (over two years). At the time of opposition, the planet is nearest the Earth, and therefore at its brightest. This change in brightness is most noticeable with Mars, whose distance from the Earth can vary considerably; the other superior planets are at such great distances that there is very little change in brightness from one opposition to another. The effect of altitude is, however, of importance, for at a December opposition the planet will be among the stars of Taurus or Gemini, and can then be at an altitude of more than 60 degrees in southern England. At a summer opposition, when the planet is in Sagittarius, it may only rise to about 15 degrees above the southern horizon, and so make a less impressive appearance.

Mars, whose orbit is appreciably eccentric, comes nearest to the Earth at an opposition at the end of August; it may then be brighter even than Jupiter, but rather low in the sky in Aquarius. These favourable oppositions occur every fifteen or seventeen years (1924, 1941, 1956, 1971), but in this country the planet is probably better seen at an opposition in the autumn or winter, when it is higher in the sky. Oppositions of Mars occur at an average interval of 780 days, and during this time the planet makes a complete circuit of the sky.

Jupiter is always a bright planet, and comes to opposition a month later each year, having moved, roughly speaking, from one Zodiacal constellation to the next.

Saturn moves much more slowly than Jupiter, and may remain in the same constellation for several years. The brightness of Saturn depends on the aspect of its rings, as well as on the distance from Earth and Sun. The rings are now open at their widest, and the planet is a brilliant object when at opposition.

Uranus, *Neptune* and *Pluto* are hardly likely to attract the attention of observers without adequate instruments, but some notes on their present positions in the sky will be found in the March, April and May notes.

Phases of the Moon, 1974

New Moon				*First Quarter*				*Full Moon*				*Last Quarter*			
	d	h	m		d	h	m		d	h	m		d	h	m
				Jan.	1	18	06	Jan.	8	12	36	Jan.	15	07	04
Jan.	23	11	02	Jan.	31	07	39	Feb.	6	23	24	Feb.	14	00	04
Feb.	22	05	34	Mar.	1	18	03	Mar.	8	10	03	Mar.	15	19	15
Mar.	23	21	24	Mar.	31	01	44	Apr.	6	21	00	Apr.	14	14	57
Apr.	22	10	17	Apr.	29	07	39	May	6	08	55	May	14	09	29
May	21	20	34	May	28	13	03	June	4	22	10	June	13	01	45
June	20	04	56	June	26	19	20	July	4	12	40	July	12	15	28
July	19	12	07	July	26	03	51	Aug.	3	03	57	Aug.	11	02	46
Aug.	17	19	02	Aug.	24	15	38	Sept.	1	19	25	Sept.	9	12	01
Sept.	16	02	45	Sept.	23	07	08	Oct.	1	10	38	Oct.	8	19	46
Oct.	15	12	25	Oct.	23	01	53	Oct.	31	01	19	Nov.	7	02	47
Nov.	14	00	53	Nov.	21	22	39	Nov.	29	15	10	Dec.	6	10	10
Dec.	13	16	25	Dec.	21	19	43	Dec.	29	03	51				

All times are G.M.T.

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MONTHLY NOTES, 1974

January

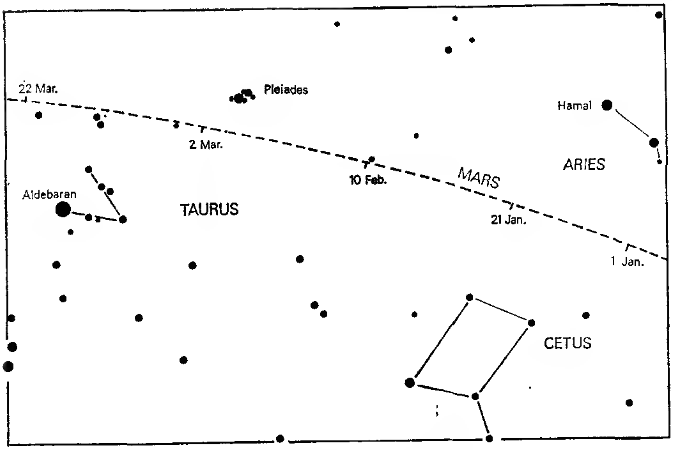
Full Moon: 8 January *New Moon*: 23 January

Earth is at perihelion (nearest to the Sun) on 4 January, its distance from the Sun being then about 91,400,000 miles (147,100,000 km).

Mercury is in superior conjunction on 9 January, and begins its appearance as an evening star at the end of the month. The bright planet Jupiter is then in the same part of the sky, but both planets are very low in the south-west at sunset.

Venus is a brilliant evening star (magnitude −4·3 to −3·5), setting about two hours after the Sun at the beginning of the month, but rapidly drawing in to inferior conjunction on the 23rd. After this date, Venus becomes a morning star until November, but its appearance will be less impressive than usual during 1974.

Mars is an evening star, easily recognized in the south as soon as it grows dark. It is moving direct in Aries, and at the beginning of the month will be seen a few degrees south of Hamal (see diagram). Its brilliance rapidly fades (magnitude −0·4 to +0·5) as its distance from the Earth increases. There is no opposition of Mars in 1974, and apart from its appear-



Mars (January to March)

ance this month it will not be a very conspicuous object for the rest of the year.

Jupiter is an evening star in Capricornus, visible in the south-west after sunset. The planet sets about three hours after the Sun at the beginning of the month, but as it moves rapidly towards conjunction this interval becomes shorter. In early January, Jupiter is near Venus, but Venus is farther to the west, and much the brighter of the two (magnitudes: Venus −3·5, Jupiter −1·6).

Saturn is an evening star in Gemini. It is still a brilliant object, having recently been at opposition (23 December 1973), and its retrograde motion will carry it back into Taurus in mid-January. Its position will then be to the west of the figure of Gemini, at the point where Gemini, Taurus, and Orion meet. There is no opposition of Saturn in 1974, and the planet will not be as bright as this (magnitude −0·3 to 0·0) until January of next year. The apparent path of Saturn during 1974 is shown on the diagram on page 76.

PERIHELION AND APHELION

The Earth is at periphelion this month, and its distance from the Sun is over three million miles less than will be the case at midsummer in the northern hemisphere. The effect upon the seasons of this varying distance is not so great as might be imagined. The seasons, of course, are due to the Earth's 23½ degree axial tilt. Theoretically, summers in the southern hemisphere are shorter but hotter than those in the north, while the winters are longer and colder; the effect is detectable, but is largely masked by the fact that the southern hemisphere contains so much more ocean than the northern.

On Mars, where there is no ocean and where the orbital eccentricity is much greater, the differences between the two hemispheres are very marked indeed. At its perihelion, Mars is 26 million miles closer to the Sun than at aphelion; and, of course, the axial tilt is much the same as ours. Therefore, the climate in the southern hemisphere is relatively extreme. The south polar cap can become much larger than that over the north pole; on the other hand it has been known to vanish altogether during Martian midsummer, whereas there is always some white deposit left in the far north.

Planet	*Distance from the Sun in millions of miles*		*Difference between perihelion and aphelion*	*Orbital Eccentricity*
	Perihelion	*Aphelion*		
Mercury	28·6	43·4	14·8	0·206
Venus	66·8	67·7	0·9	0·007
Earth	91·4	94·6	3·2	0·017
Mars	128·4	154·9	26·5	0·093
Jupiter	460·4	507·3	46·9	0·048
Saturn	837·7	936·5	98·8	0·056
Uranas	1700	1868	168	0·047
Neptune	2771	2819	48	0·009
Pluto	2754	4586	1832	0·248

The above table is interesting as it gives some data concerning aphelion and perihelion distances of the planets. The greatest range is for Pluto, whose orbit is very curious indeed, and is also inclined to the Earth's at an angle of 17°. The inclination of Mercury's orbit is 7°, that of Venus rather over 3°, and those of all the other planets less than 2°.

It is rather pointless to discuss 'seasons' on the giant planets, whose surfaces are gaseous; with Jupiter, the axis is almost perpendicular to the plane of the orbit, so that changes in what we may call seasons will be controlled mainly by the 47,000,000-mile difference between perihelion and aphelion distance. Uranus has an axial tilt of 98 degrees, so that there are times when a pole faces the Sun (as will next happen in 1985), and the Uranian 'calendar' must be very peculiar, particularly since there are 65,000 'days' in every 'year', and every 'year' each pole has a period of sunlight and a subsequent period of darkness each lasting for twenty-one Earth-years!

Pluto is exceptional in every way. At its perihelion it can come within the orbit of Neptune, though the 17-degree orbital inclination means that there is no fear of a collision. For some years to either side of the next opposition date, 1989, Pluto will forfeit its title of 'the outermost planet'. When the next aphelion occurs, in the second decade of the twenty-second century, Pluto will be so faint that it will be beyond the range of all but giant telescopes; it will also be far south in the sky. The surface temperature will be much lower than it is at present, though Pluto is always an intensely cold world; from there, the Sun would appear no larger than Jupiter does to us, though it would still be very brilliant.

THE RECESSION OF MARS

At the start of the year Mars is still brighter than any star, apart from Sirius (and Canopus, which is not visible from Britain). Its apparent diameter will be rather over 11 seconds of arc, and the phase will be pronounced; only 91 per cent of the sunlit hemisphere will be turned toward us, so that Mars will appear distinctly gibbous in shape.

A moderate telescope will still show the main dark features (except in the rather unlikely event of a major dust-storm being in progress). However, as the weeks go by Mars will become smaller and smaller, and even large instruments will show little upon it. Therefore, planetary observers are recommended to make the best possible use of this last period of fruitful observation of Mars at the 1973 opposition.

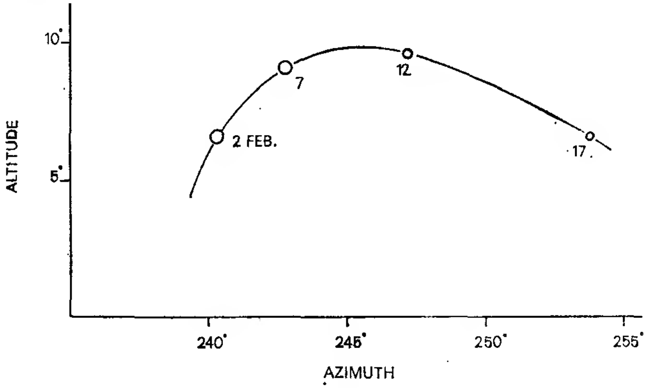
TEST YOUR HORIZON!

In January evenings the brilliant blue star Vega is at its lowest; Capella, on the opposite side of the north celestial pole, is practically at the zenith. Observers in Britain may find it interesting to see whether they can catch sight of Vega just above the horizon; it will provide a test of the atmospheric clarity. From places further south (New York, for instance) Vega is not circumpolar.

February

Full Moon: 6 February *New Moon*: 22 February

Mercury is at greatest eastern elongation (18°) on 9 February and is in inferior conjunction on the 24th. The planet may be seen as an evening star in early February a few degrees south of west after sunset. The diagram shows the changes in altitude and azimuth (true bearing from the north through east, south and west) of Mercury on successive evenings when the Sun is six degrees below the horizon; this will be about half an hour after sunset at this time of year. The changes in brightness are roughly indicated by the size of the circles, and it will be seen that Mercury is brightest before the date of greatest elongation.



Venus reaches its greatest brilliancy as a morning star on 27 February (magnitude −4·3). It rises about two hours before the Sun and is a conspicuous object in the south-east.

Mars is an evening star, setting about an hour after midnight. Its direct motion to the east carries it into Taurus in mid-

February, and by the end of the month is will be seen nearly three degrees south of the Pleiades, but still much brighter than any of the neighbouring stars (magnitude +0·5 to +1·0).

Jupiter is in conjunction with the Sun on the 13th, and will not be visible during February.

Saturn is still a bright evening star (magnitude 0·0 to +0·2) and reaches a stationary point on 27 February on the borders of Orion and Taurus. It is visible for most of the night, setting an hour or so before dawn. Saturn will be seen quite close to the gibbous moon in the early evening of 3 February, and observers in the British Isles with adequate instruments may be able to see an occultation of the planet in the afternoon. At Greenwich, Saturn will disappear at the dark limb of the Moon at $15^h 08^m$, and will reappear at the bright limb at $15^h 34^m$. See notes on page 67.

THE CRAB NEBULA

During February evenings one object of particular interest is above the horizon. This is the Crab Nebula, which lies close to the third-magnitude star Zeta Tauri. The diagram shows where to find it; it is of course much too faint to be seen with the unaided eye, since its integrated magnitude is only 8·4, but a modest telescope will show it as a blur of light.

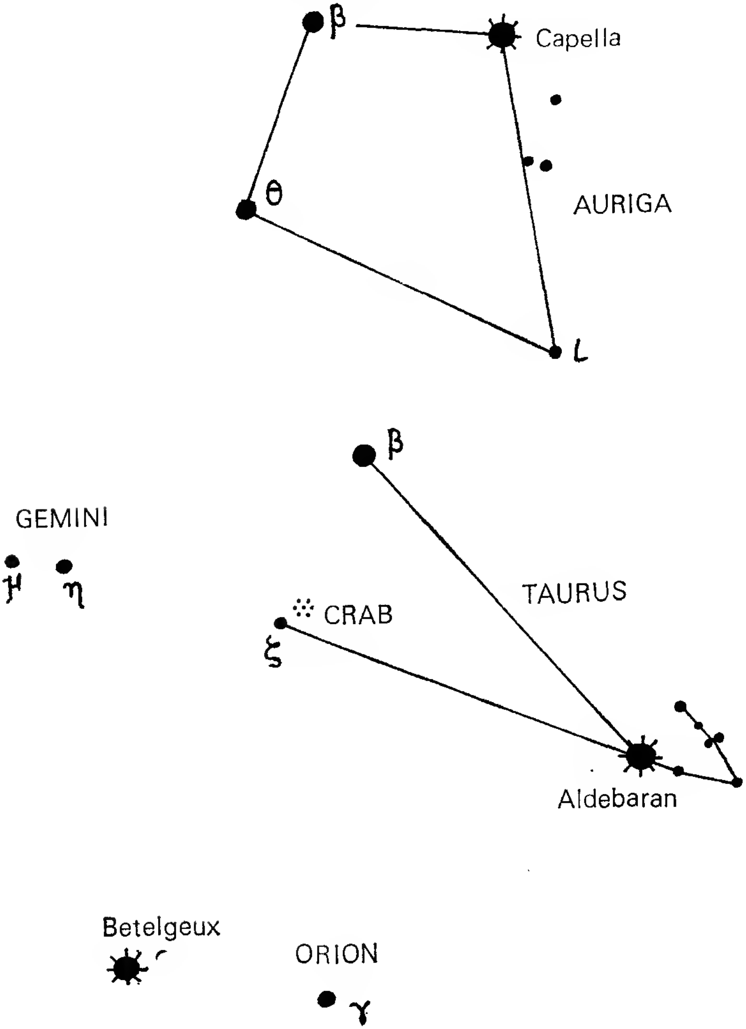
The Crab was discovered by John Bevis in 1731. Little attention was paid to it; it was re-discovered independently in 1758 by Charles Messier, and is the first entry in Messier's catalogue of clusters and nebulæ, so that it is still known as M.1. (It is also NGC 1952, from Dreyer's New General Catalogue.) Messier described it as containing 'no star; it is a whitish light, elongated like the flame of a taper'. Lord Rosse, in 1844, called it 'a cluster . . . probably greater power would bring out its filaments, and it would then assume the ordinary form of a cluster'. Rosse did not make many mistakes, but this was one. The Crab is no cluster; it is undoubtedly the remnant of a supernova seen in the year 1054.

This supernova was recorded by Chinese and Japanese astronomers, and must have been as brilliant as Tycho's Star of 1572, since it was visible to the naked eye and was bright enough to be visible in broad daylight for over three weeks. Modern photographs taken with large telescopes show an intricate structure, and demonstrate that the gas is still expanding outward from the old explosion-centre.

The rate of expansion is over 700 miles per second, and the density of the gas has been estimated at less than one fifty-million-millionth of the Earth's air at sea-level. Reckoning backwards, we can deduce that the expansion started about 900 years ago, and this is an extra proof of the identity with the remnant of the Chinese supernova. Of course, the actual outburst took place much earlier than A.D.1054. For many years the distance of the Crab was estimated as 3600 light-years, but it now seems that the true distance is about 6000 light-years, so that we are looking back far into the past.

As well as sending us visible light, the Crab is a radio source; indeed, it is one of the strongest radio emitters in the sky. Luckily it is so near the ecliptic that each year, on or about 14 June, the Sun passes within 2½ degrees of it, so that the Crab is occulted by the solar corona; studies of the way in which this affects the radio waves received from the nebula have been of tremendous value. The Crab is also a source of X-rays and gamma-rays. Not surprisingly it has been the object of intensive research, and one astronomer commented that there were only two kinds of modern astronomy: the astronomy of the Crab Nebula, and the astronomy of everything else!

Moreover, the Crab contains a pulsar which has been optically identified. There seems little doubt that this is the supernova remnant, and it has been called the 'power-house' of the nebula; most authorities believe it to be a neutron star, of small size but incredible density. All in all, the Crab is unique in our experience, and for this reason alone it is worth find-



ing — even though its outward appearance in a small telescope is anything but striking. It is one degree north and one degree west of Zeta Tauri.

ADOLPHE QUETELET AND THE PERSEID METEORS

This month is the centenary of the death of one of Belgium's most distinguished astronomers (Lambert) Adolphe (Jacques) Quételet, who was born in Ghent on 22 February, 1796 and died at Brussels on 17 February, 1874.

Quételet studied astronomy at the Paris Observatory, and became an official lecturer at Ghent when aged only eighteen. In 1828 he became Director of the Brussels Observatory, and it was from here, in 1839, that he published an important work, *Principal Appearances of Falling Stars.* His statistical ability led him on to the identification of the Perseid shower, which is seen every August, and is much the most consistent of all the annual showers.

Meteors tend to move round the Sun in shoals; each time the Earth passes through a shoal, we see a shower of shooting-stars. Because the meteors are moving through space in virtually parallel paths, the meteors of a shower seem to diverge from one particular point (just as to anyone standing on a bridge overlooking a motorway, the lanes of the motorway will seem to converge toward a distant point). The August meteors have their 'radiant' in Perseus, and Quételet realized that this must be because they belong to the same swarm.

Quételet was also active in developing methods of simultaneous observations of astronomical, meteorological, and geodetic phenomena at points scattered all over Europe. His interests were wide, and he spent much time in social work and studies; in addition he was a skilled lecturer and organizer. However, in astronomy he will always be best remembered for his work on the study of meteors. The Perseids will again be on view this summer, between 27 July and 15 August; and in 1974 they will be prominent, because moonlight will not interfere when the shower is near its maximum activity.

March

Summer Time in Great Britain and Northern Ireland commences on 17 March.

Full Moon: 8 March *New Moon*: 23 March

Equinox: 21 March

Mercury is at greatest western elongation (28°) on 23 March and is then a morning star, although it is badly placed for observation in the northern hemisphere. There is again some risk of confusion with the bright planet Jupiter, which is also low in the south-east at dawn.

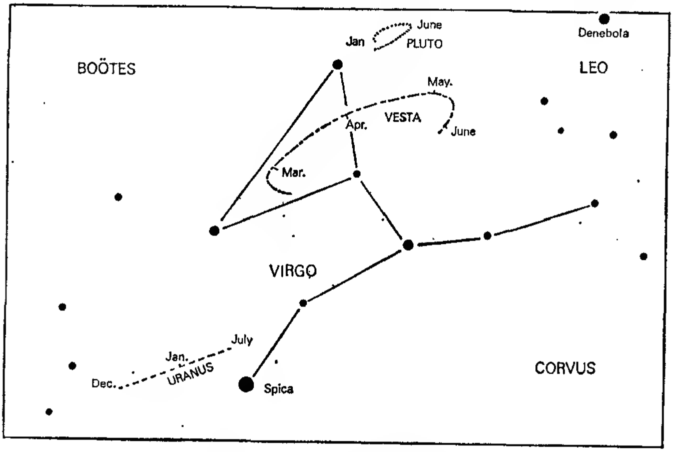
Venus is still a brilliant object in the morning sky, rising in the south-east about two hours before the Sun. Magnitude −4·3 to −4·0.

Mars will be found in the south at sunset at the beginning of March, and although it is still fading (magnitude +1·0 to +1·5) it may easily be recognized among the stars of Taurus. Mars passes 7 degrees north of Aldebaran on the night of 17 March, and it may be seen that the two objects are then of comparable magnitudes (Mars +1·2, Aldebaran +1·1). The planet sets north of west about an hour after midnight.

Jupiter is now a morning star in Aquarius and will remain in this constellation for the rest of the year. The planet rises about an hour before the Sun at the end of March.

Saturn is an evening star visible until the early morning hours. It is still quite bright (magnitude +0·2 to +0·3) and is moving direct towards the figure of Gemini. On the night of 2 March Saturn will be seen close to the Moon, which will then be a day past First Quarter, and the occultation which occurs shortly before midnight should be well worth seeing. At Greenwich, disappearance at the dark limb is predicted for 23ʰ 48ᵐ and Saturn will reappear at the bright limb at 44ᵐ past midnight. See notes on p. 67.

Pluto is at opposition on 26 March, but is too faint to be seen with small instruments (magnitude +14). Owing to the considerable inclination of its orbit, the planet appears well to the north of the ecliptic (see diagram). Its distance at opposition is decreasing each year, and in 1974 it will be 2787 million miles (4485 million km).



Vesta, Pluto and Uranus

Vesta is at opposition on 31 March but will be at its nearest to the earth on 6 April at a distance of 118 million miles. This is the brightest of the minor planets, and on this occasion it should be just visible to the naked eye (magnitude +5·9), and readily found with a pair of binoculars (see diagram).

THE OCCULTATION OF SATURN

Occultations of stars are relatively common, and provided one of the earliest proofs that the Moon has virtually no atmosphere. At an occultation, the star snaps out as suddenly as a candle-flame in the wind — except on rare occasions; 'fades' have been observed, but seem to be due to causes other than any lunar atmosphere. (If a star is a close binary, it may well disappear in two stages, giving the impression of a fade.) When the planet Venus occults a star, there are perceptible fading effects as the star passes behind the planet's atmosphere before disappearing.

Occultations of planets are less common, but are interesting to observe. In retrospect, it is worth remembering some comments made by W. H. Pickering, who paid great attention to problems of lunar and planetary astronomy. In his book about the Moon, published in 1903, he wrote as follows:

> '. . . The Moon frequently passes in front of, and occults, small stars, but the displacement produced by the lunar atmosphere at such times is so small that we cannot measure it. We cannot therefore say what the exact density of the Moon's atmosphere really is. On the assumption that it is proportional to the refraction we may state that its density cannot exceed the 1/10,000th part of our own (Annals of the Harvard College Observatory, XXXII, 239). . . Perhaps the strongest evidence that we possess of a lunar atmosphere, based on direct observation, is found when the Moon occults a bright planet. Under these circumstances a dark band is always seen crossing the planet, tangential to the edge or limb of the Moon. This absorption is never seen at the dark limb of the Moon, indicating thereby that the absorbing medium, whatever it is, is condensed to a solid by the intense cold that must prevail during the lunar night. Some astronomers have attempted to explain this dark band as a mere contrast effect, due to the fact that the surface of the Moon is brighter than that of the planet; this would not be so were Venus the planet occulted by the Moon, but unfortunately favourable occultations of Venus are rare.

> Nevertheless, we have a very convincing proof that the dark band is a real phenomenon and not a mere subjective effect of contrast, inasmuch as it has been photographed. A photograph of the occultation of Jupiter was taken at the Harvard Observatory station at Arequipa, Peru, on 12 August 1892. The two equatorial belts of the planet were well shown, while the dark absorption band due to the Moon's atmosphere was seen at right angles to them and tangent to the surface of the Moon.'

Ideas of this sort seem strange now, and some of Pickering's views were admittedly extreme (he did not even rule out the possibility of swarms of insects on the Moon). And we have conclusive proof that the density of any lunar atmosphere is so low that it could never produce any measurable effect of refraction, to say nothing of a dark absorption band across an occulted planet. The Arequipa photograph is not convincing – and there seems little doubt that the 'band' is a photographic rather than a real effect.

However, observations of this kind have been made on several occasions; and even though the atmospheric explanation is ruled out, the phenomena are worth searching for. Saturn is not an ideal planet for such investigation, owing to the presence of the rings, but observers of this month's occultation should be very much on the alert for anything unusual.

JOHANN MADLER – THE GREAT LUNAR OBSERVER

Of all the famous names in the story of lunar observation, that of Johann Mädler stands out. It was he who may be regarded as the founder of careful, accurate mapping of the Moon, and the outline chart which he produced in collaboration with his friend Wilhelm Beer remained the best available map for several decades – even though it was compiled before the age of photography, and with a very small telescope.

Johann Heinrich von Mädler was born at Berlin on 29 May, 1794. His parents died when he was still young, and as he had three young sisters to support he was not able to enter University until 1818. He then went to the University of Berlin, and in 1822 became a teacher. He gave private lessons to augment his income, and one of his pupils was Wilhelm Beer, a Berlin banker, who had an observatory equipped with a 3¾ in. Fraunhofer refractor. Beer and Mädler decided to undertake a close study of the Moon, and to compile a map which would be better than anything previously produced. There were, in fact, no really good charts of the Moon; the 'father of selenography,' Johann Schröter, had never compiled a full map, and one was urgently needed.

Beer and Mädler worked patiently away, and in 1837-8 they published their map, together with a detailed account of every important formation. They also extended the nomenclature, keeping to the system introduced by Riccioli in 1651 (each feature being named after some important person, usually an astronomer). Their work was universally acclaimed, and was regarded as the final authority on all lunar matters. It is a great pity that their book, *Der Mond nachseinen Kosmichen und individuellen Verhältnissen, oder allgemeine vergleichende Selenographic,* has never been translated into English; this would be worth doing even now, for its historical value.

Beer and Mädler did not confine their attention to the Moon. They also studied Mars, and produced a map of the Martian features also, though they were naturally handicapped by the fact that the telescope used was of small aperture.

The excellence of the lunar map has never been questioned, and the skill with which it was compiled is quite amazing; Beer made notable contributions, though Mädler was the main observer. Unfortunately their main work ended in 1840, when Mädler left Berlin to become Director of the Observatory at Dorpat in Estonia – then, as now, part of Russia. Thenceforth Mädler occupied himself with problems of cosmology, in which he was much less successful. In 1846 he put forward a theory according to which the star-system revolved round a central sun, and he identified this central sun with Alcyone, the brightest star in the Pleiades cluster. The theory was based on no substantial evidence, and met with little support, despite Mädler's excellent reputation.

He retired in 1865, and returned to Germany. By then Beer had been dead for many years, and there is no record that Mädler undertook any more observation, though he did produce an excellent book on the history of astronomy. He died at Hanover on 14 March, 1874.

Oddly enough, Beer and Mädler unwittingly held back the progress of lunar observation for some time! They regarded the Moon as inert; and it was commonly believed that if nothing ever happened on the lunar surface, and the great map represented everything that could be seen, nothing useful could be gained in further study. This view was altered only in 1866, with the sensational report by Schmidt of the alleged alteration in the crater named Linné on Mädler's map. But this lack of observation was not Mädler's fault, and he will always be remembered as the man who produced the first really good map of the Moon.

April

Full Moon: 6 April *New Moon*: 22 April

Mercury remains too close to the Sun to be seen during the month.

Venus is at greatest elongation west (46°) on 4 April, but this is not a very favourable elongation, the planet being well south of the Sun. As a result, it rises in the south-east less than two hours before sunrise. Venus passes about one degree north of Jupiter on the morning of the 15th (magnitudes: Venus −3·9, Jupiter −1·7).

Mars continues to be seen as an evening star, and as it moves into higher northern declinations, it sets about the same time each night – about an hour after midnight. At the beginning of the month the planet is in Taurus, north of the figure of Orion, but it moves into Gemini in the last week of March. Mars passes about two degrees north of Saturn on 20 April, but there is a marked contrast between the apparent brightness of Mars and that of Saturn (magnitudes: Mars +1·7, Saturn +0·3).

Jupiter rises in the east in Aquarius about an hour before sunrise. The conjunction with Venus on 15 April is mentioned in the note above, and although Jupiter is growing brighter (magnitude −1·6 to −1·8) Venus is far more brilliant, and it should be possible to find both planets in the bright dawn sky. At the beginning of April, Venus is moving quite rapidly to the east, so that at the beginning of the month, it will be seen to the west of Jupiter, but after the 15th, it will be to the east.

Saturn is visible during the evening, but sets at midnight at the end of the month. The planet moves into Gemini in mid-

April, and it will be seen to the north of the foot of the figure of Gemini as it sets in the north-west. The conjunction with Mars on the 20th is mentioned in the note above.

Uranus is at opposition on 16 April in Virgo, a few degrees north-east of Spica (see diagram on p. 65). The distance of Uranus from the Earth at opposition is about 1620 million miles (2607 million km), and its magnitude will then be +5·7, so that it should just be visible to the naked eye. A small telescope will show the planet as a greenish disk. The apparent path of Uranus is shown on the diagram in the March Notes on page 65.

ENCKE'S COMET

This spring sees the fiftieth known return of Encke's Comet, which was the first-identified of the periodical comets with the exception of Halley's. It has a period of only 3·3 years, and its orbit is so well known that there is no fear that it will be missed.

The story of the comet really began on 17 January, 1786, when Méchain, at Paris, discovered a small telescopic comet near the star Beta Aquarii. As a comet-hunter Méchain was second only to the great Charles Messier; and he at once notified Messier, who was held up by bad weather but who managed to confirm the comet on 19 January. It was seen on the same night by J. D. Cassini, and was described as devoid of a tail, but fairly bright and well defined, with a nucleus.

On 7 November, 1795 a faint comet was discovered by Caroline Herschel, who described it as being 5′ in diameter but with no nucleus. Heinrich Olbers saw it on 21 November, but by then it was very faint indeed. The mathematician Prosperin tried to calculate an orbit, but found that no parabola would satisfy the observations.

Then, on 19 October, 1805, Thulis at Marseilles discovered a comet which could just be seen with the naked eye. On 1 November, Huth described a 3° tail. Johann Encke, at

Berlin, calculated an orbit, but gave a period of 12·1 years.

The next chapter in the story of the comet was opened on 26 November, 1818 by Jean Pons, who discovered a small telescopic comet in Pegasus. It remained on view for nearly seven weeks, so that a long series of observations was obtained. Encke made an attempt to calculate an orbit; he found that no parabola would do, and that the orbit must be elliptical, with a period of about 3½ years. It was then that he looked back over the records, and was struck with the similarity in orbit between Pons' comet and those of Méchain, Caroline Herschel, and Thulis. Over a period of six weeks Encke made a long series of calculations, taking all the planetary perturbations into account, and finally decided that the comets were identical, so that it had passed through perihelion seven times between 1786 and 1818 without being observed. He calculated the next perihelion as being due on 24 May, 1822 – it was retarded by nine days by the influence of Jupiter.

Encke's calculations proved to be very accurate. The comet was discovered by Rümker, at Paramatta in New South Wales, on 2 June, 1822, shortly after the perihelion passage. Encke was able to make more accurate calculations for the next return, that of 1825; it was duly discovered, by Valz, on 13 July of that year. Since then, almost no return has been missed.

Comets are usually named after their discoverers, in which case the name assigned would presumably have been Méchain-Herschel-Thulis-Pons! However, in exceptional circumstances the name of the mathematical investigator of the orbit is given; and it was agreed that this comet should be known as Encke's. (The comets of Halley and Crommelin are other instances.)

Many points of interest in connection with Encke's Comet may be noted. The period has shortened slightly, and there are times when the comet approaches Mercury to within 4,000,000 miles (as in 1848). But of particular significance is the decline in brightness. When Thulis found it, in 1805, it was visible with the naked eye. Nowadays it is well below naked-eye visibility, though when it is best placed it can be seen with modest telescopes. Also, it seems that the tail is much less evident now than it used to be. For instance, in 1871 the Rev. H. C. Key described, and drew, a fan-shaped tail; but during recent apparitions no true tail has been in evidence.

It has been said that comets are short-lived by astronomical standards, and we know of some former short-period comets which have disintegrated; Biela's is the best example of this. It has even been suggested that Encke's Comet is nearing the end of its career, and that it will 'die' before the end of the twentieth century. This is probably much too extreme; but it does seem that there is little chance of the comet again attaining naked-eye visibility. Astronomers will hope that it will continue to return every 3¼ years; after all, it is an old friend!

THE DIAMETER OF VESTA

The first-discovered minor planets – Ceres, Pallas, Juno, and Vesta – are usually nicknamed the 'Big Four'. In fact this is not entirely accurate. Ceres, Vesta, and Pallas are almost certainly the largest members of the asteroid swarm, but Juno, with an estimated diameter of only 150 miles, may be surpassed by several others, notably by No. 10, Hygeia (about 220 miles), which, however, is more remote and is consequently fainter.

The mean distances of the 'Big Four' from the Sun, in millions of miles, are: Ceres 257, Pallas 257, Juno 248, and Vesta 219. The mean opposition magnitudes are respectively 7·4, 8·7, 8·0, and 6·0. Vesta comes to opposition on 31 March this year, and the calculated magnitude is 5·9, which means that it should be visible with the naked eye; if you know just where to look for it, you will be able to make it out as a very faint star (provided that the sky is really clear). It is thus over a magnitude brighter than Ceres, which comes next in order of brilliancy.

Vesta is closer to us than Ceres, but not so large. Up to recent times the diameters of the 'Big Four' were given as 427 miles for Ceres, 280 for Pallas, 150 for Juno, and 241 for Vesta. This would give Vesta much the highest albedo, or reflecting power, and there were suspicions that it might really be somewhat larger than the official figure.

The diameter has been recently re-measured by Dr D. A. Allen (one of our regular contributors to these *Yearbooks*), using infra-red techniques. His value for Vesta is 370 miles. There seems little doubt that the result is accurate; it brings the albedo down to an acceptable figure, and means that Vesta is considerably larger than Pallas, so that only Ceres in the whole swarm is its superior. However, its mass is very low, and there is no chance that it retains any trace of atmosphere.

It must, however, be added that when the diameters of other large asteroids – such as Leses and Pallas – are measured by infra-red techniques, they too may be found to have diameters which are greater than the currently accepted values.

URSA MAJOR AT THE ZENITH

There can be few people who cannot recognize Ursa Major, the Great Bear, with its seven stars making up the 'Plough' or 'Big Dipper' pattern. During evenings in April it is worth noting that as seen from Europe and the northern United States the Bear is practically overhead, making it even easier to identify.

May

Full Moon: 6 May *New Moon*: 21 May

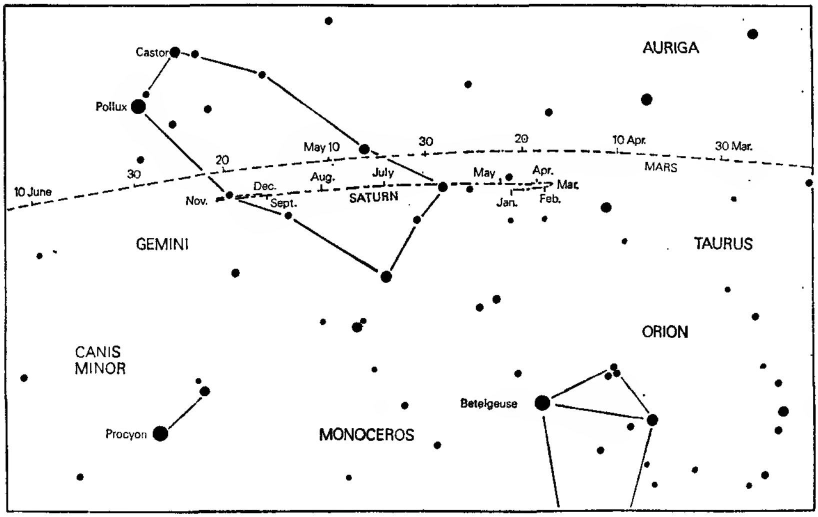
Mercury is in superior conjunction on 4 May but towards the end of the month it becomes an evening star in the west. Saturn will then be in the same part of the sky, and there is some risk of confusion as the planets are of comparable magnitude.

Venus continues to be seen as a morning star, rising in the east about an hour before the Sun. During the month the planet crosses the equator on its way north. Magnitude −3·7 to −3·5.

Mars is still an evening star, setting north of west at midnight in early May. The planet will be found in Gemini, passing about 5 degrees south of Pollux on the 29th. By the end of May, Mars will be 200 million miles from the Earth, and it is now moving round the far side of its orbit. This causes it to fade still further (magnitude +1·7 to +1·9), and this may be seen by comparing it with Castor (+1·6) and Pollux (+1·2).

Jupiter rises in the east about two hours before sunrise at the beginning of May. It will be seen in Aquarius, south of the right-hand side of the Great Square of Pegasus (see diagram on page 94). Although not as bright as Venus, it should be possible to find it in the bright summer sky before dawn (magnitude −1·8 to −2·0).

Saturn sets in the north-west in the late evening. It is still quite a bright object (magnitude +0·3) forming a little group with the stars at the foot of the figure of Gemini as it sets (see diagram).



Saturn and Mars

Neptune is at opposition on 30 May, when it will actually be in the constellation Ophiuchus, some degrees north of Antares. The planet is not visible to the naked eye (magnitude +7·7) but may be seen in a small telescope as a greenish disk. The distance of Neptune at opposition is about 2720 million miles (4380 million km). (See diagram on page 86.)

The Outer Giants

Both the outer giants, Uranus and Neptune, are on view this month. Uranus was in opposition on 16 April, and remains in Virgo, not far from the first-magnitude star Spica. Neptune is in opposition at the end of May, and is not far from Antares, though its position is actually in Ophiuchus – a constellation which intrudes into the Zodiac for some distance between Scorpius and Sagittarius, though it is not officially recognized as a Zodiacal constellation. Uranus is just visible to the naked eye, but Neptune is well below the limit, though binoculars will show it easily.

Uranus was discovered by Herschel in 1781; in view of its faintness it is not surprising that it had been overlooked earlier, though in fact it had been recorded as a star by various astronomers, including Flamsteed. Neptune was tracked down in 1846, as a result of its perturbations upon Uranus. Notes on the strange story of the discovery of Neptune were given in the 1973 *Yearbook* (pages 76-8).

The two outer giants are very similar, and have been described as twins; they are certainly more alike than Venus and the Earth. The main difference between them is that Uranus has its 98-degree axial tilt, whereas that of Neptune is only 28° 48′.

With very remote planets, accurate diameter-measurements are far from easy. For many years the value for Uranus was given as 29,300 miles and that of Neptune 27,700 miles. There was no doubt that Neptune is rather the more massive of the two, and has a higher escape velocity; 15·5 miles per second, as against 13·9 for Uranus – but with a planet attended by satellites it is easier to measure the mass than the diameter. With the old value for Neptune, the surface gravity was calculated to be 1·4, taking that of the Earth as unity, which is greater than that of Saturn (1·2) or Uranus (1·1), and less only than that of Jupiter (2·6).

Then, however, the diameter of Neptune was re-measured in a very ingenious way. At Herstmonceux, Gordon E. Taylor calculated that the planet would occult a star. The duration of the occultation would give a very precise value for the diameter of the planet. The observations were duly made, and from them Taylor was able to show that the real diameter is 31,500 miles. So Neptune really is larger than Uranus, as well as being more massive; and the surface gravity comes down to a much more reasonable figure of 1·2.

Many attempts have been made to detect surface details on the outer giants. With Neptune these efforts were doomed from the outset, since the apparent diameter never exceeds 2·2 seconds of arc – as against a maximum of over 50 seconds of arc for Jupiter, 21 for Saturn and 3·7 for Uranus. The colour of Neptune is somewhat bluish. There may well be Jovian-type belts, but it is impossible to be sure. Even the rotation period is not known as accurately as might be desired, though it is certainly in the region of 14 hours.

Uranus holds out more possibilities, and observers have reported various markings in the form of bright and dark belts; it must, however, be remembered that owing to the exceptional inclination of the axis, there are times when we are looking straight at one of the planet's poles.

A new method was used in 1973, when photographs of Uranus were taken with a 36-inch telescope carried aloft in a balloon (Stratoscope II) to a height of 15 miles. The resolution achieved was 0·15 seconds of arc. Altogether seventeen photographs were taken, and have been analysed by R. E. Danielson, M. G. Tomasko, and B. V. Savage of the United States. Even after computer processing, the pictures revealed no details whatsoever! From an analysis of the distribution of brightness over the disk, Danielson and his colleagues suggest that Uranus is uniformly covered with a thin deck of methane cloud, above which is a semi-transparent atmosphere made up of molecular hydrogen. They measured the equatorial diameter as 51,800 km; if this is accepted, then Uranus and Neptune must again be regarded as almost exactly equal in size.

If the lack of details is accepted, it must be assumed that the markings shown by visual observers on Earth are not real. It is suggested that the axial inclination of 98 degrees produces uneven heating of the planet, and that there are no stable 'wind' zones able to produce belts similar to those of Jupiter and Saturn (and possibly Neptune). However, this depends only upon the one series of Stratoscope photographs, and it may be premature to conclude definitely that Uranus is entirely devoid of observable detail. It would certainly be worth making a careful study, but this is not likely to be attempted in the near future, since it would require extensive use of a very large telescope.

VENUS AND JUPITER

Now that both these planets are visible in the morning sky, there is a good opportunity for comparing their brightness. The difference between the two is about a magnitude and a half – that is to say, about the same as the difference between Sirius and Vega or Capella. No other planet can rival them, except for Mars on the rare occasions of a perihelic opposition.

June

Full Moon: 4 June *New Moon*: 20 June

Solstice: 21 June

Mercury is at greatest eastern elongation (24°) on 4 June, and since it is then in high northern declination it may be possible to find the planet to the north of west after sunset. Mercury is close to Saturn on 2 June, Saturn being slightly brighter than Mercury at this time. Both planets are moving towards conjunction, and Mercury will be in inferior conjunction on 30 June.

Venus rises nearly two hours before the Sun to the north of east in Taurus. The planet is now rather less than half as bright as it was in February and March (magnitude −3·4) and will remain so for the rest of this year.

Mars has now faded to the second magnitude, and sets in the late evening. The planet moves into Cancer at the beginning of the month (see diagram on page 76).

Jupiter rises about midnight in the east in Aquarius, and grows brighter (magnitude −2·0 to −2·2). Although the summer night sky is never really dark, Jupiter is quite a conspicuous object among the faint stars in this neighbourhood.

Saturn sets more than an hour after the Sun, in the north-west in Gemini, but it is moving rapidly towards conjunction on 30 June, and will only be visible at the beginning of the month, when it sets about an hour after the Sun.

A partial eclipse of the Moon on 4 June will be visible in Europe, beginning at $20^{h}\ 39^{m}$ G.M.T., and ending at $23^{h}\ 58^{m}$.

More than eighty per cent of the Moon will be eclipsed at the maximum phase at $22^h\ 16^m$. (See notes on page 113.)

A total eclipse of the Sun occurs on 20 June, the central track lying in the Indian Ocean, and just crossing the extreme south-west coast of Western Australia. A partial eclipse will be seen throughout the rest of Australia. (See notes on page 113.)

TOTAL ECLIPSES FOR THE REST OF THIS CENTURY

A total eclipse of the Sun is a superb spectacle, and it is unfortunate that they are so rare, at least from any particular point on the Earth's surface. The last to be visible in England occurred as long ago as 1927. It may be useful to give the dates of the total eclipses due before the year 2000. They are as follows: 1976, October 23; 1977, October 12; 1979, February 26; 1980, February 16; 1981, July 31; 1983, June 11; 1984, November 22; 1985, November 12; 1986, October 3; 1988 March 18; 1990, July 22; 1991, July 11; 1992, June 30; 1994, November 3; 1995, October 24; 1997, March 9; 1998, February 26; and 1999, August 11. Of these, the last is the only one to be visible as a total eclipse from England. The track begins east of New York, and crosses Cornwall.

Total lunar eclipses are more often seen, since totality covers any part of the Earth's surface from which the Moon is above the horizon; but though an eclipse of the Moon is interesting and beautiful to watch, it cannot be compared with the magnificence of a total eclipse of the Sun.

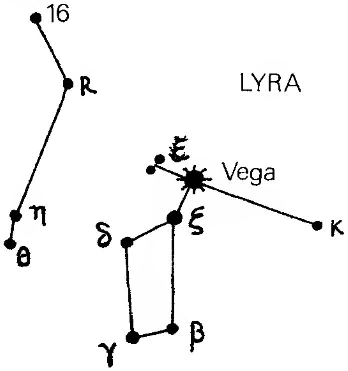
ÅNGSTRÖM AND HIS UNIT

A famous name in physics – and astronomy – is that of Anders Jonas Ångström, who died a hundred years ago. He was Swedish, and was born at Lögdö on 13 August 1814. He was educated at Uppsala, and in 1843 became an observer at the Uppsala Observatory, which was then (as now) one of the most celebrated in Sweden. In 1858 he assumed the chair of physics at Uppsala, in succession to Adolph Svanberg. Ångström was above all a spectroscopist, and undertook fundamental research. Astronomically, he is best remembered for his work in connection with the solar spectrum. In 1862 he announced that hydrogen existed in the Sun's atmosphere, and in 1868 he published his great map of the solar spectrum – which has long been accepted as the standard, though his measurements were slightly affected by the fact that the 'metre' which he used was a little too short. In 1867 he was the first to examine the spectrum of the aurora borealis, and to measure the characteristic bright line in the yellow-green region. He died at Uppsala on 21 June, 1874. His son, Knut Ångström, became professor of physics at Uppsala in 1896.

Anders Ångström has been given the honour of having his name attached to the unit used for measuring wavelengths of light (and also x-rays). It is equal to one ten-millionth of a millimetre. The usual abbreviation is Å, though in some countries where the Swedish letter is not easy to set in print this is given merely as A. His name has also been given to a small crater on the lunar Mare Imbrium.

R Lyræ

The study of variable stars is a favourite amateur pursuit, and much valuable work is done. For faint variables, of course,



a powerful telescope is needed, but there are a few stars which are readily observable with binoculars. One of these is R Lyræ, in the little constellation which is dominated by the steely brilliance of Vega. It is excellently displayed this month.

The position of R Lyræ is shown in the diagram; the R.A. is $18^h\ 53^m\ 49^s$, declination +43° 52′ 45″. Its spectrum is of type gM6, and its parallax a mere 0″.006. R Lyræ is therefore a Red Giant star, and, like so many members of its class, is appreciably variable in light. It is classed as 'semi-regular', so that its behaviour can never be predicted. The official period is 47 days, but this is subject to marked fluctuations; so for that matter is the range. At its brightest it can attain magnitude 4·0; at minimum it drops to 5·0 at times.

This range is not great, and so the variations are slow. Moreover, even though R Lyræ is visible with the naked eye, it is not easy to observe accurately, because there is a singular dearth of suitable comparison stars anywhere near it. The closest are Eta and Theta Lyræ, each of which is officially ranged as of magnitude 4·5; there is also Flamsteed t 16 Lyræ, but this is of magnitude 5·1, and is rather too faint to be useful except when R is near minimum. Most observers will prefer to use binoculars for estimating it, but a wide field is needed, as otherwise all the comparison stars will be out of the field of view.

Semi-regular stars of small range are not usually intensively studied by professional astronomers, and amateurs can make themselves very useful. There has been much discussion as to the accuracy obtainable without using specialized equipment (such as photometers). It is true to say that the experienced observer can usually estimate down to one-tenth of a magnitude; this is generally good enough for semi-regular and irregular variables, as well as the Mira-type stars of long period.

It would be misleading to call R Lyræ a suitable subject for observation by beginners, but it is worth attempting to draw up a light-curve, particularly as it is so far north that from Europe and the northern United States it is visible for so much of the year. However, do not be surprised if your first attempts at a light-curve yield some very strange-looking results!

Like all M-type stars R Lyræ is decidedly red. This colour cannot be readily seen with the naked eye, as the star is too faint, but it is very obvious in binoculars, and and contrasts with both Eta and 16 Lyræ (white) and Theta (slightly yellowish).

Many other semi-regular variables are known. Among them is Alpha Herculis, where the range is between magnitudes 3 and 4, and of course Betelgeux in Orion, which can sometimes rival Rigel but at minimum is not much brighter than Aldebaran.

July

Full Moon: 4 July *New Moon*: 19 July

Earth is at aphelion (farthest from the Sun) on 5 July, when its distance will be 94,500,000 miles (152,100,000 km).

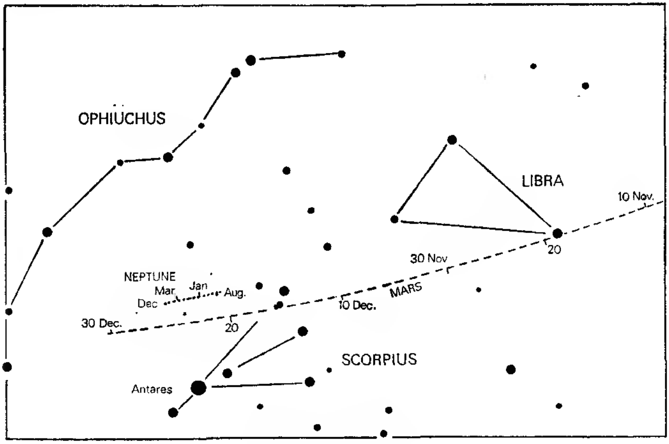
Mercury is at greatest western elongation (20°) on 22 July, and may perhaps be seen in the north-east at dawn for a few days after this date as its brightness increases. The planets Venus and Saturn are in the same part of the sky at this time, but Venus is much brighter and higher in the sky, while Saturn is unlikely to be seen in the bright dawn sky.

Venus continues to rise in the north-east about two hours before sunrise. The planet passes 4 degrees north of Aldebaran on 4 July, and will be very close to Saturn on the morning of 31 July, but both of these conjunctions will be difficult to observe with the naked eye.

Mars is still visible as an evening star for about an hour after sunset. In the first week of July, the planet moves into Leo, and will pass less than a degree north of Regulus on 26 July. Mars is at aphelion on 5 July (about 155 million miles from the Sun); this is about 27 million miles greater than its distance at perihelion in July of last year.

Jupiter rises in the east in mid-evening and will be in the south at sunrise. It continues to grow brighter (magnitude -2·2 to -2·4) and reaches a stationary point on 8 July in northern Aquarius, on the border with Pisces. After this date its motion will be retrograde as it approaches opposition. See diagram on page 94.

Saturn now begins to appear as a morning star, rising in the north-east about two hours before sunrise in the centre of the figure of Gemini. The conjunction of Saturn with Venus on the morning of 31 July is mentioned in the note above (magnitudes Venus −3·4, Saturn + 0·3).



Neptune and Mars

How Low Can You See?

During July, the southern constellations of Scorpius and Sagittarius are at their best as seen from northern countries such as Europe and the New York area. These are really splendid groups – as will be very evident to anyone looking at them from, say, South Africa or Australia. So far as British observers are concerned, however, they are always very low, and parts of them are virtually unobservable. We also have to reckon with the effects of extinction, or dimming due to the Earth's atmosphere. For a star at an altitude of 1 degree, the extinction amounts to 3 magnitudes, which is a very large amount. The value for a star at 10° above the horizon is only one magnitude, and above 45° altitude extinction can be neglected for all practical purposes. Against this, effects of refraction seem to 'lift' a star and make it appear slightly higher than it really is. In the following notes, refraction is neglected.

The declination of a star is its angular distance north or south of the celestial equator. To find the limit of visibility for any particular observer, all that need be done is to subtract the observer's latitude from 90 degrees. As an example, consider, Birmingham, England, where the latitude is N. 52° 29′. (Of course, Birmingham covers a wide area, but this value is at least approximately correct.) Subtract 52° 29′ from 90°, and we arrive at a figure of 37° 31′. This means that a star north of declination +37° 31′ will never set, while a star south of declination –37° 31′ will never rise.

To show how the method of calculation works, let us take a few samples from the British Isles; one in the south (Selsey in Sussex), one in the Midlands (Birmingham), one in south Scotland (Edinburgh), one in north Scotland (Thurso) and one in the Shetland Islands (Lerwick). Details are as follows:

	Latitude, N	*Limiting visibility, S.dec., and limiting circumpolar appearance, N.dec.*
Selsey	50° 44′	39° 16′
Birmingham	52° 29′	37° 31′
Edinburgh	55° 57′	34° 03′
Thurso	58° 25′	31° 35′
Lerwick	60° 10′	29° 50′

Now let us take some stars 'near the limit'. The limiting value for southern visibility is also the limit of northern circumpolar appearance for a star in the far north of the sky.

	Mag.	*Decl. S.*
Antares in Scorpius (Alpha Scorpii)	1	26° 19′
Nunki in Sagittarius (Sigma Sagittarii)	2	26° 22′
Fomalhaut in Piscis Austrinus (Alpha Piscis Austrini)	1	29° 53′
Kaus Australis in Sagittarius (Epsilon Sagittarii)	2	34° 25′
Theta Centauri	2	36° 07′
Shaula in Scorpius (Lambda Scorpii)	2	37° 04′
Acamar in Eridanus (Theta Eridani)	3	40° 30′
Canopus in Carina (Alpha Carinæ)	–0¾	52° 40′

Consider Selsey first. The limit is −39° 16′. Of the stars in our list, all are actually north of this apart from the last two, and so in theory they rise, particularly if refraction is taken into account; but the theoretical rising of Shaula, the bright star in the Scorpion's sting, is only 2° 12′. Extinction accounts for 2½ magnitudes, so that it will be very difficult to see Shaula from this position even under ideal conditions (a completely transparent horizon over the sea). From Birmingham it will be hopeless to try to see the star, even if it were possible to avoid any sky-glow due to artificial lights, and from Scotland it definitely does not rise. On the other hand, from Selsey the bright star Fomalhaut, in the Southern Fish, attains quite a respectable altitude (over 9 degrees) but it never rises from Lerwick, and it is none too easy to glimpse from most of Scotland.

Sagittarius, on view during July evenings, is cut by the limiting line for Britain. Its two brightest stars are Nunki and Kaus Australis; Nunki can be seen easily from England but with considerable difficulty from north Scotland, while Kaus Australis will hardly be seen from anywhere north of Birmingham. Antares is visible from anywhere in Britain, but from Lerwick its altitude will never exceed 3½ degrees; Canopus is definitely below the British limit, and so is Acamar, the 'Last in the River', which was ranked of the first magnitude in ancient times and is now below the third. (Whether there has been any real fading is another matter.)

New York has a latitude of N.40° 20′, and so the limit is 49° 40′. All the stars in our list can be seen easily apart from Canopus, which does not quite rise above the horizon.

It would be an interesting project to make some careful observations to see just how far south the northern observer can see. The principle can be applied to any star, from any position on the surface of the Earth; no mathematics are involved apart from simple subtraction.

PALLAS

It is worth noting that Pallas, No. 2 in the list of minor planets, is at opposition this month; but it is not a favourable opposition, and the magnitude remains below 9. Pallas has a period of 4·6 years; it is notable because its orbital inclination is over 34° – much higher than for any other of the largest asteroids.

August

Full Moon: 3 August *New Moon*: 17 August

Mercury is in superior conjunction on 17 August and is too close to the Sun to be seen during the month.

Venus is still a brilliant morning star, rising to the north of east about two hours before the Sun. The planet is now moving south again, and this reduces its period of visibility each morning before sunrise.

Mars is moving towards conjunction, and now sets less than an hour after the Sun. It is only of the second magnitude and there is little chance of seeing this planet until it reappears as a morning star at the end of October.

Jupiter is a brilliant evening star (magnitude −2·5) rising shortly after sunset in the east. It is now moving retrograde in Aquarius, and will be visible late at night in a dark sky. With the coming of the darker evenings there is an excellent opportunity of watching the ever-changing series of phenomena of Jupiter's four great satellites with a good pair of binoculars or a small telescope.

Saturn is still a morning star, but now rises less than two hours after midnight, and will be visible in a really dark sky. It is now moving direct in Gemini, and will be seen to be brighter than any of the stars in this constellation (magnitude +0·3 to +0·4). (See diagram, p. 76.)

John Knight Fotheringham and Secular Acceleration

The name of John Knight Fotheringham may well be unfamiliar to most people – even to astronomers – but he undertook some remarkably interesting work which is worth recalling now, on the centenary of his birth. He was born at Tottenham on 14 August, 1874, and was educated at Oxford. From 1904 to 1915 he was Lecturer in Ancient History at London University, and was appointed Reader in Ancient Astronomy at Oxford in 1925 – a position which he retained until his death on 12 December, 1936.

Fotheringham was particularly interested in ancient eclipses, and did his best to date them accurately both from historical records and from mathematical calculations. With eclipses sufficiently far back, it is always found that there is a discrepancy between theory and observation; and this is due, mainly, to what is called the Moon's secular acceleration. The basic cause is the slowing-down in the Earth's rotation, due to tidal friction.

The average increase in the length of the 'day' is 0·00000002 seconds. This does not seem much; but as each day is 0·00000002 seconds longer than the preceding one, then a century (36,525 days) ago the length of the day was shorter by 0·00073 seconds than it is now. Taking an average between then and now, the length of the day was half this value (0·00036 seconds) shorter than at the present time. But since 36,525 days have elapsed, the total error is 36,525 × 0·00036 seconds, or 13 seconds; and this is a measurable amount.

When the Moon's position is 'calculated back', therefore, there will be a discrepancy. The Moon will seem to have moved too far – that is to say, too fast; and this is what is called 'secular acceleration'. And as we are dealing with a value of almost one minute every 400 years, the effect shows up when we calculate the times of ancient eclipses. This is what Fotheringham spent so long in studying. It goes to show that even a tiny amount of slowing-down in the Earth's rotation can be detected.

Another result of this slowing-down is that the Moon is receding from the Earth, but as the increase in distance is only about four feet per year we need be in no hurry to observe the Moon before it vanishes into deep space! Moreover, the increase will not continue indefinitely. Theoretically, it will stop when the Moon has reached a distance of 370,000 miles, and when the 'day' and the 'month' are equal at 47 times the length of our present day. Subsequently, solar tidal effects would bring the Moon closer again. There have been graphic descriptions of how the Moon will eventually come within the Roche limit (the Earth's danger-zone) and be disrupted, providing us with a Saturnian-type system of rings; but there are many objections to this – not least the time-scale, since it seems that even if the process would occur at all it would not do so before changes in the Sun destroy the Earth-Moon system in its present form.

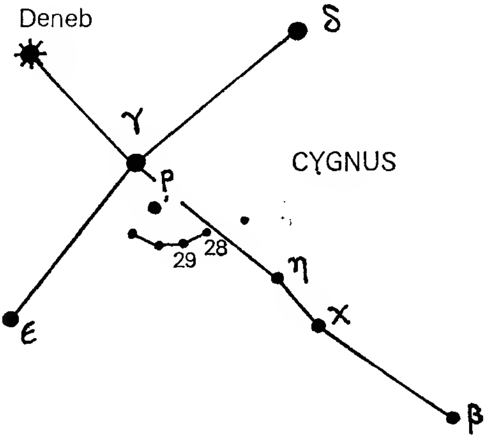
THE PERSEIDS

No notes on August skies would be complete without a reminder that the Perseid meteor stream will be on view. This year the Moon will interfere only with the first part of it; by the second week of the month the skies will be dark, and so, weather permitting, the Perseids will be spectacular.

P CYGNI

The magnificent constellation of Cygnus contains a wealth of interesting objects, as well as its X-shape of bright stars. One of the fascinating members of the group is P Cygni, which is the prototype of a class made up of very luminous, unstable stars.

To the naked eye, or with a telescope, there is nothing striking about it; but it has an interesting history. The first record of it seems to have been left by an astronomer named Blaeu, who in 1600 saw it shining as a star of the third magnitude. Since it had not been previously noted, it was regarded as a nova, and is still often listed as such, though we now know that it is certainly not a nova in the ordinary sense of the term. In 1606 it began to fade, and by 1626 it was invisible with the naked eye. It is next heard of, in the records, in 1654, when it brightened to just about magnitude 6. After minor fluctuations, it reached magnitude 5·2 in 1715, and for many years now it has oscillated round a mean magnitude of about 4·9. Suitable comparison stars are Flamsteed 28 Cygni (magnitude 4·8) and Flamsteed 29 (5·0). Binoculars are ideal for observing it.



Spectroscopic studies indicate that mass is constantly streaming outward from the surface of P Cygni, though not as rapidly as with novæ at the time of an outburst. Emission lines as well as absorption lines are seen in the spectra, and it seems that there is a large, expanding atmosphere round the star.

Though P Cygni has shown no major variations in brightness now for over two and a half centuries, it is far from stable, and it may at any time start to fluctuate more noticeably. For this reason it is worth observing; the chart given here should enable it to be found without difficulty, not far from the second-magnitude star Gamma Cygni in the centre of the 'Northern Cross'.

September

Full Moon: 1 September   *New Moon*: 16 September

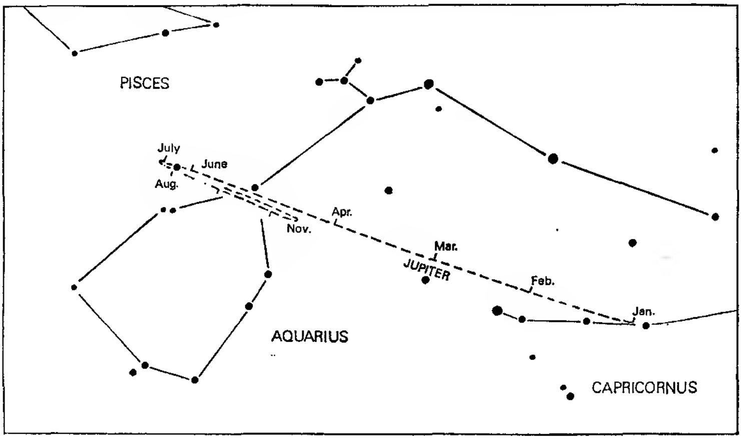
Equinox: 23 September

Mercury is theoretically an evening star at the end of September, but it is not very bright, and is too low in the western sky to be seen at sunset.

Venus continues to be visible as a morning star, rising about two hours before the Sun at the beginning of September, but it is moving rapidly south, and by the end of the month it rises only an hour before sunrise.

Mars is now on the far side of its orbit, moving towards conjunction in October, and is too close to the Sun to be seen.

Jupiter comes to opposition on 5 September, when its distance from the Earth will be 370 million miles (595 million km).



Jupiter, 1974

This is almost the minimum distance possible (but it will be slightly less in 1975) and the planet is therefore at its maximum brilliance (magnitude −2·5), a splendid object, visible all night and in the south at midnight. The bright star low in the south at this time (see Star Charts 9L and 10R) is Fomalhaut, which is the leading star in the southern constellation Piscis Austrinus (the Southern Fish) and is 30 degrees south of the equator.

Saturn rises at midnight to the north of east at the beginning of September. It is moving direct in Gemini, and is bright enough (magnitude +0·3) to be easily recognized among the familiar stars of this constellation. With the coming of the darker evenings the possessor of a small telescope will have the opportunity of observing the rings (still widely open, though now beginning to close again) and the large satellite Titan.

TITAN

Now that Saturn is becoming well-placed again, the satellite system is observable under favourable conditions. There are ten satellites in all. Of these, Janus will remain out of view until the rings are almost edgewise-on, which will not be until 1979-80. Mimas and Enceladus are difficult objects, because both are faint and close to Saturn; Phœbe, the most remote satellite and the only one with a retrograde orbit, is extremely faint, and Hyperion, of about the thirteenth magnitude, also requires a relatively large aperture. Of the remaining satellites, Rhea and Iapetus are comparatively bright; Rhea is above the tenth magnitude, and so, when at its maximum (west of Saturn) is the variable and perplexing Iapetus. Modest telescopes will also show Dione and Tethys. But the principal satellite is Titan, a planet-sized world which is notable as being the only satellite in the Solar System definitely known to have an atmosphere.

Titan's mean magnitude is 8·3, so that it is visible with a very small instrument. Its mean distance from the centre of

Saturn is 760,000 miles, and its revolution period is 15 days 22½ hours. The orbit is not far from circular (eccentricity 0·03) and, like all the larger satellites apart from Iapetus, it moves practically in the plane of the equator and the ring-system. It was discovered by Huygens in 1655, and was thus the first known planetary attendant excluding our Moon and the four Galilean satellites of Jupiter.

The diameter is uncertain within certain limits. It is unquestionably more than 2500 miles, and may be as much as 3500; the mean of these extremes, 3000 miles, is probably not very far from the truth. In any case, Titan is strictly comparable in size with Mercury, and of all other satellites it is rivalled only by Ganymede and Callisto in Jupiter's system and Triton in Neptune's. The escape velocity is 1·7 miles per second.

The atmosphere was discovered by G. P. Kuiper as long ago as 1944, and is assumed to be composed chiefly of methane; it is tenuous, though there have been recent suggestions that it may be rather denser than was previously thought. One interesting comment is that Mercury (escape velocity 2·6 miles per second) has virtually no atmosphere. The explanation is that Titan is much the colder of the two; if the temperature were only slightly higher, the atmosphere would escape.

It is not easy to find out the densities of satellites. Taking water as unity, the density of the Moon is 3·3; the only known satellites thought to be denser are Europa, Jupiter's second attendant (3·7) and Triton (5·1), though these values are bound to be very arbitrary. Most of Saturn's satellites have low densities. Pride of place goes to Dione (3·2); Iapetus comes next (about 3?) and this value has also been attributed to Hyperion. The density of Titan on this scale is assumed to be 2·3. The mass is 1/4150 that of Saturn itself.

The colour is generally said to be somewhat yellowish. With very large telescopes, vague surface patches have been seen, but to attempt to draw up a map of Titan would be very premature!

Shadow transits of Titan are not difficult to observe, when they occur (none will take place this year; they are seen only when the ring-system is much less open). It is also possible for Titan's shadow to eclipse Rhea. This has been observed on one occasion: on 8 April, 1921. The phenomenon was predicted by A. E. Levin and L. J. Comrie, and was witnessed by six observers: Levin, Comrie, P. H. Hepburn, E. A. Attkins, F. Burnerd and C. J. Spencer, using telescopes ranging from 12 inches aperture down to only 4½ inches (Spencer). For more than two-thirds of the duration of the eclipse, which amounted to a total of 44 minutes, Rhea disappeared from view.

THE GREAT BEAR AT ITS LOWEST

During autumn evenings Ursa Major, the Great Bear, is at its lowest, though from Britain it is still well above the horizon. The southernmost of the seven Plough stars is Alkaid (Eta Ursæ Majoris), whose declination is +49° 33′. Using the method given in the July notes, it is easy to find out from which countries it remains circumpolar. Alkaid is the most remote of the seven stars; its distance is 210 light-years. It is also the most luminous member of the pattern. It and Dubhe, the brighter of the two Pointers to the Pole Star, are moving through space in a direction opposite to that of the other five members, and so over a sufficiently long period the Bear will lose its characteristic shape – though the proper motions are so slight that the pattern looks virtually the same now as it did when civilization began on Earth.

October

Summer Time in Great Britain and Northern Ireland ends on 27 October.

Full Moon: 1 and 31 October *New Moon*: 15 October

Mercury reaches its greatest eastern elongation (26°) on 1 October, but it will then be very low in the western sky at sunset as seen from the northern hemisphere. Observers in the southern hemisphere have an excellent opportunity of seeing this planet on this occasion, although it will not be as bright as it can be when elongation occurs at perihelion.

Venus is moving rapidly towards superior conjunction and is now too close to the Sun to be seen.

Mars is in conjunction with the Sun on 14 October and after this becomes a morning star. By the end of the month it rises in the east less than an hour before the Sun, but it is still only of the second magnitude, and too close to the Sun to be seen.

Jupiter is an evening star setting to the south of west about two hours after midnight. It is now beginning to fade (magnitude −2·4 to −2·2) but is still the brightest star in the night sky.

Saturn rises in the late evening and will be in the south at sunrise. It is growing a little brighter (magnitude +0·3 to +0·2) and is moving direct in Gemini, reaching a stationary point on 31 October near the star Delta Geminorum (see diagram on page 76).

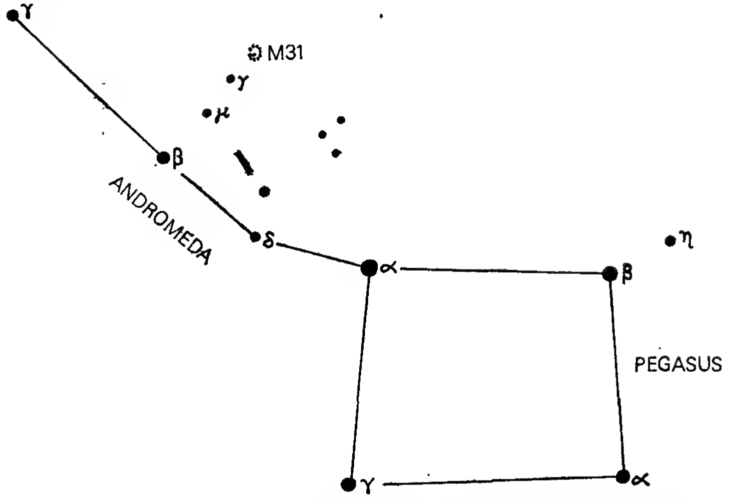
THE BARONESS AND THE SUPERNOVA

During evenings in autumn the Square of Pegasus dominates the southern aspect of the sky. Leading off from it, in the general direction of Capella, is the line of stars marking Andromeda, the princess of the legend about Perseus and the Gorgon's Head. Andromeda looks nothing like a princess, but the constellation is conspicuous, since its three leading stars (Alpheratz, Mirach, and Almaak) are of the second magnitude; Alpheratz is a member of the Square, and should logically belong to Pegasus – indeed, it used to be known as Delta Pegasi, though it has now officially become Alpha Andromedæ.

The most famous object in Andromeda, and indeed one of the most famous in the sky, is the Great Spiral, Messier 31. It is visible to the naked eye on a clear night, not far from Nu, and was well known in ancient times; it was recorded by the Arabian astronomer Al-Sûfi as long ago as the year 964. The first telescopic view of it seems to have been obtained by Simon Marius in 1612; he described it as 'like the flame of a candle seen through horn'. We now know it to be an immense galaxy larger than our own, lying at a distance of 2,200,000 light-years. It is a member of our local group, and is not receding from our Galaxy. Indeed, it is actually approaching us, though this motion is due to the Sun's real rotation round the galactic centre and does not imply that the two systems are becoming closer together.

The Spiral – M.31 – contains objects of all kinds. Novæ have been seen in it, and there has been one supernova, S Andromedæ, which appeared in 1885 and was extensively observed, even though its nature was not recognized. At that time, of course, it was generally believed that the 'spiral nebulæ' were inside the Galaxy rather than being external systems.

The story of the discovery of S Andromedæ is interesting. It has been said that it was first seen on 20 August, 1885 by Hartwig at the Dorpat Observatory. At about the same time it was seen by Isaac Ward, a skilful amateur astronomer who lived in Belfast. Another independent discovery was made by a most unlikely observer – a Hungarian baroness whose knowledge of astronomy was admittedly almost nil!



The Baroness de Podmaniczky was apparently holding a house-party, and one of her guests was an astronomer, Dr De Kövesligethy. Somewhere in the house was a 3½-inch telescope, and on occasion the Baroness set this telescope up on the lawn and 'contemplated the heavens'. On 22 August she and her guest decided to look at the Andromeda Nebula, and the Baroness remarked that she could see 'a little star in the nebula'. De Kövesligethy also saw it, but both thought that the light of the full moon was causing an illusion – drowning the main part of the nebula, and making the central portion appear stellar.

In fact, what the Baroness had seen was a tremendous outburst, far greater than that of ordinary novæ, and comparable with the star which produced the Crab Nebula and with Tycho's Star of 1572. During the next few nights it was seen by other observers (for instance Max Wolf at Heidelberg on 25 August, and Professor Ludovic Gulley at Rouen on 27 August). There is also a report that Gulley saw it even before Hartwig, though without realizing its importance. Its maximum magnitude was 6, so that it was on the fringe of naked-eye visibility; and one can well judge its real luminosity. Remember, the star S Doradûs in the Large Magellanic Cloud is invisible with the naked eye, even though it is a million times as powerful as the Sun and is less than one-tenth the distance of the Andromeda Spiral. By the end of September the magnitude had dropped to 10, and then faded further until it was lost to view in the general background glow.

Opinions about the star were divided. The eminent French astronomer Trouvelot felt strongly that it was entirely separate from the nebula, and merely lay in the foreground. Others were not so sure; but so long as the nature of the Spiral itself remained unknown, no definite conclusions about the star could be reached. It was only in 1923 that there came the final proof that M.31, and others of its kind, were far beyond the boundaries of our Milky Way.

Many novæ have been seen in the Spiral since then, but no more supernovæ; it is unfortunate that S Andromedæ made its brief appearance before astronomers on Earth had developed equipment suitable to study it! Of course, another supernova may appear in the Spiral at any time; meanwhile, S Andromedæ remains unique so far as M.31 is concerned in our experience.

Not surprisingly, no other astronomical observations by the Baroness de Podmaniczky are on record. There can surely be no other instance of someone with no knowledge of science looking casually at the sky through a small telescope and discovering a supernova.

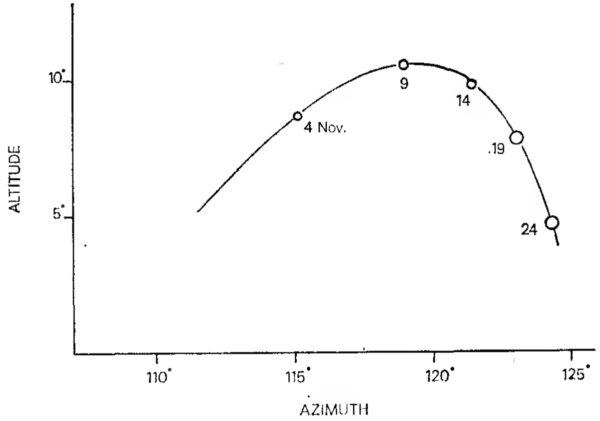
Britain and the Clock

It is worth stressing that after 27 October, civil time in Britain reverts to GMT instead of being one hour ahead. The experiment of making 'summer time' permanent has been tried, and discontinued at least for the moment. Needless to say, summer time is never used in recording astronomical observations; and when looking up time in scientific handbooks, remember to make allowance for it when it is in civil use.

November

New Moon: 14 November *Full Moon*: 29 November

Mercury is at greatest western elongation (20°) on 10 November, and may be seen for a few days in the east at dawn. The diagram shows the changes in altitude and azimuth of Mercury on successive mornings when the Sun is six degrees below the horizon; this is about half an hour before sunrise in mid-November. The changes in brightness are roughly indicated by the size of the circles, and it will be seen that Mercury is brighter after the date of western elongation.



Venus is in superior conjunction on 6 November. After this date it becomes an evening star, but will be slow to appear in the western sky at sunset.

Mars begins to appear as a morning star, rising south of east at about the same time (6h.) each morning. In early November it moves into Libra, and will be close to Alpha Libræ

(Zuben-el-Genubi) about 20 November (see diagram on page 86). Mars is now a little brighter (magnitude +1·8) but will be difficult to find in the bright sky at dawn.

Jupiter is an evening star, setting at midnight in mid-November. The planet is retrograding in Aquarius, but reaches a stationary point on 3 November, after which it moves direct once more. (Magnitude −2·2 to −2·0.)

Saturn rises in mid-evening and is now quite a conspicuous object (magnitude + 0·2 to 0·0) moving retrograde in Gemini.

A total eclipse of the Moon on 29 November visible generally in Asia and Australasia. In the British Isles only the end of the eclipse will be visible, the Moon rising totally, or almost totally eclipsed. (See notes on page 113.)

FAINT ALPHAS

Below the Square of Pegasus lies Pisces, the Fishes – officially the last constellation of the Zodiac, though since it now contains the vernal equinox it really ought to be the first. Pisces is entirely unremarkable, and is one of the most obscure of all the Zodiacal groups. It is, however, ancient, and there is even a mythological legend attached to it. Venus and Cupid once escaped from the giant Typhon by throwing themselves into the River Euphrates and changing themselves temporarily into fishes; subsequently two fishes were placed in the sky in memory of this rather curious episode!

There are few notable objects in Pisces, though Alpha, sometimes known by its old proper name of Al Rischa, is a fairly easy double. Actually, it is not the brightest star in the group; this distinction goes to Eta, which is slightly more conspicuous even though it is still well below the third magnitude.

The system of allotting Greek letters to stars was introduced by Johann Bayer in 1603. The principle is to letter the brightest star in a constellation Alpha, the second Beta, and so on down to Omega, the last letter in the Greek alphabet. There are however various exceptions to the rule – Pisces being one. The most glaring examples are Corvus and Sagittarius. In Corvus there are four stars of the third magnitude or above, making up a conspicuous little quadrilateral; these are Gamma, Beta, Delta, and Epsilon, while Alpha Corvi is a full magnitude fainter. The other faint Alpha is in Sagittarius, where the two brightest stars are Epsilon and Sigma; their magnitudes are respectively 1·8 and 2·1, while Alpha is a modest 4.

Of course, in many cases where Alpha is not the leader of a constellation the difference is so slight that naked-eye estimates might be in error; thus in Ursa Major Epsilon (Alioth) is 1·79 and Alpha (Dubhe) fractionally fainter at 1·81 – though in this case it seems that Bayer lettered the principal stars in order of right ascension rather than brilliancy. There are also cases of revisions of constellation boundaries. In Puppis the brightest star is Zeta; but Puppis is part of the dismembered constellation of Argo Navis, and Alpha, Beta, Gamma, Delta, and Epsilon of Argo are now in different parts. (Alpha is, of course, Canopus.)

The following are cases of 'faint Alphas', where the Alpha is at least 0·4 magnitude fainter than the brightest star in the constellation.

Constellation	*Brightest star*	*Magnitude of Alpha*
Cancer	Beta, 3·5	4·3
Capricornus	Delta, 2·9	3·5 (a double star!)
Cetus	Beta, 2·0	2·5
Corvus	Gamma, 2·6	4·0
Draco	Camma, 2·2	3·6
Gemini	Beta, 1·2 (Pollux)	1·6 (Castor)
Sagitta	Gamma, 3·5	4·4
Sagittarius	Epsilon, 1·8	4·0

The Alphas of Andromeda, Aquarius, Camelopardus, Delphinus, Hydrus, Libra, Microscopium, Monoceros, Pegasus, Pisces, and Ursa Major are slightly fainter than the leader of each constellation. We also have two variable Alphas, in Hercules and Orion; Alpha Herculis (Rasalgethi) is a semi-regular red giant ranging between 3 and 4, whereas the two leaders, Beta and Zeta, are ranked as 2·8; and, of course, Betelgeux in Orion is not quite equal to Rigel, though when it is at maximum the two are strictly comparable. (Herschel, on one occasion, even made Betelgeux the brighter, though this was a naked-eye estimate and cannot be regarded as precise.) Finally, there are suspicions that Castor and Pollux are less equal than they used to be in ancient times, though the evidence is very uncertain.

LINNE AND LUNAR ECLIPSES

A total lunar eclipse is beautiful to watch. The degree of darkness, and the colour of the eclipsed Moon, must depend on the conditions in the Earth's atmosphere; remember, the only light reaching the Moon from the Sun during totality has been refracted through the air surrounding our world.

When the Earth's shadow engulfs the Moon, the temperature on the lunar surface drops rapidly. Observers have often looked for possible effects on special features, and for a long time attention was concentrated upon Linné, the little formation in the Mare Serenitatis which was largely responsible for the revival of interest in the Moon after 1866. In that year Julius Schmidt reported that the crater which had been drawn by all previous observers, and which Mädler had named Linné in honour of the great Swedish botanist Linnæus, had disappeared, to be replaced by a white spot. Later it was defined as a craterlet surrounded by a bright area.

In the days before the idea of reaching the Moon was taken at all seriously, it was believed that the whiteness might be due to some deposit such as 'hoarfrost', and it was also claimed that Linné had increased in prominence immediately after the end of an eclipse – presumably because precipitation or condensation had occurred during the period of cold. Of course, ideas of this kind are now very out of date, and there is not the slightest chance that anything of the kind can happen; the lunar atmosphere is negligible. However, the observations of Linné were interesting, and even if erroneous (as is the general and very logical view today) they are worthy of comment. Unfortunately this month's lunar eclipse will be only partly visible from Britain; all the same, lunar enthusiasts will no doubt examine Linné as soon as the Moon reaches a reasonable height above the horizon.

December

New Moon: 13 December *Full Moon*: 29 December

Solstice: 22 December

Mercury is in superior conjunction on 19 December, and will not be visible during the month.

Venus begins to appear as an evening star in the south-west at sunset towards the end of the year, but sets about an hour after the Sun. It is now well south of the equator and is therefore better placed for observation in the southern hemisphere. Venus should be a splendid object in the evening skies in the Spring of 1975, when it reaches its greatest eastern elongation in June.

Mars continues to rise at about 6h. in the south-east. It rapidly crosses Scorpius to enter the constellation Ophiuchus, which here intrudes into the Zodiac. On 23 December, Mars will be seen 5 degrees north of Antares (magnitude +1·2) but comparison of Mars with Antares (the 'Rival of Mars') will be difficult in the morning sky. The planet is a little brighter (magnitude +1·8 to +1·7) but the next opposition of Mars, when it will be more than three magnitudes brighter, does not take place until December, 1975.

Jupiter sets in the late evening to the south of west, and although it is still fading (magnitude −2·0 to −1·8), it is a very noticeable object in this part of the sky. It is moving direct in Aquarius and will pass into Pisces in 1975.

Saturn is now close to opposition (6 January) and as soon as it is really dark, it may be seen in the east, among the stars of Gemini. The planet is now a really brilliant object (magnitude 0·0 to −0·2) but the forthcoming opposition will not be quite as bright as in December 1973, since the rings, which contribute very largely to the brightness of the planet, are not as fully open as they were at that opposition.

A partial eclipse of the Sun on 13 December will be visible in North and Central America. The eclipse begins just before sunset in the extreme south-west of Ireland. (See notes on page 113.)

The Star of Bethlehem

Each year Venus appears in the evening sky toward the end of the year, people are inclined to ask: 'Was this the cause of the Star of Bethlehem story?' And though the matter has been discussed briefly in several previous *Yearbooks*, it seems appropriate to enter into a little more detail now that Venus is once again a 'Christmas star'.

So far as the Star of Bethlehem is concerned, we must admit that our information is scanty. The story is told only by St Matthew. None of the other books of the bible mention it at all; there are no records of any unusual astronomical event of about that period, and so we have almost nothing to guide us. All we can really do is to work out what the Star was *not*.

Even the dates are vague; Christ was certainly not born on 25 December A.D.1, and the possible error amounts to several years, though it seems that the actual date of Christ's birth was earlier than A.D.1 rather than later. Christmas was set as 25 December by Dionysius Exiguus several centuries later, and is undoubtedly wrong. Altogether, the whole situation is decidedly nebulous.

Yet one thing is certain. The Star of Bethlehem was not Venus. The reason is quite straightforward. Venus is often visible in the evening sky; and it would be seen not only by the Wise Men, but also by everyone else. There would be nothing remotely mysterious about it. If the Wise Men really regarded Venus as something unusual, then they would not have been at all wise! The same objection rules out Jupiter, Sirius, and all other bright objects which are familiar features of the sky.

Other ideas can be discounted also, though for different reasons. A few are as follows:

(1) C. L. Ideler's theory, that there was a close conjunction of Jupiter and Saturn – so that the two planets merged into one mass, and gave the impression of a strikingly brilliant star. Alas, Ideler's calculations were wrong. There were no suitable conjunctions visible from the Middle East anywhere near the vital dates; and in any case a conjunction would have been seen by anyone who cared to look.

(2) A supernova. This seems impossible, because of the complete lack of scientific confirmation.

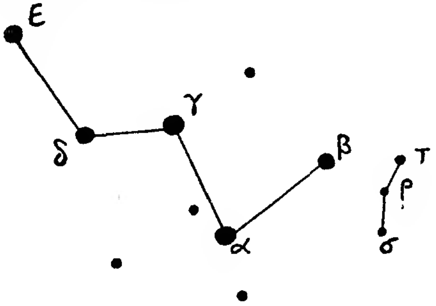
(3) Halley's Comet. There was a return in 11 B.C., but this seems rather too early; again, visibility would not have been confined to the Wise Men.

(4) Two meteors, seen at different times. This avoids the difficulty that only the Wise Men saw the star, and meteors are the only objects which would move visibly over a short period; but of course they would remain on view only for a second or two, and this does not correspond with St Matthew's description.

This is probably as far as we can go. Scientifically there is no plausible explanation for the Star of Bethlehem.

VARIABLE STARS IN CASSIOPEIA

During December evenings the familiar W-form of Cassiopeia is very high up. Three of the five stars are almost equal in brilliancy; these are Alpha (Shedir), Beta (Chaph), and Gamma, which has no official proper name. All are slightly below the second magnitude. Beta is measured as 2·26, while Shedir and Gamma are variable – Gamma certainly so, Shedir probably. Next come Delta (Ruchba) which is magnitude 2·67; Epsilon (3·4) is perceptibly fainter.



Look at the W, and you will be hard pressed to decide which is the brightest star. Shedir has long been regarded as slightly variable; its spectrum is K0, and it is distinctly orange. If it fluctuates at all, its range is very slight; probably 2·1 to 2·5 at the most. Gamma, however, is a remarkable star. In 1936 it increased to magnitude 1·6, but then declined, dropping to the third magnitude in 1940. Subsequently it recovered its old brightness, and for years now it has fluctuated slightly around a mean magnitude of 2·2. It is a star which periodically emits shells of tenuous gas, and it has been called a pseudo-nova. The spectrum is of type B, though with unusual characteristics.

Another irregular variable is Rho Cassiopeiæ, near Chaph. Its fluctuations were discovered by Miss Wells in 1901. It is an F8-type supergiant, though when it drops to minimum its spectrum more nearly resembles a star of type M; its distance is 6,500 light-years, and its diameter is thought to be several hundred times as great as that of the Sun, with 25 times the solar mass. Its extreme range in magnitude is from 4·1 to 6·2, but for most of the time it remains slightly above the fifth magnitude; well-marked minima are rare, and the last occurred as long ago as 1946. Suitable comparison stars are Sigma Cassiopeiæ (magnitude 4·9) and Tau (5·1). Naked-eye estimation is difficult, and low-power binoculars are ideal for making observations; the comparison stars are much more convenient than in the case of R Lyræ.

The Southern Skies

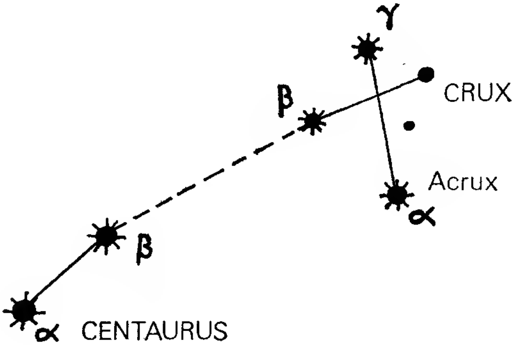
In this *Yearbook*, the star maps are, inevitably, drawn for observers in the northern hemisphere. Maps for observers who live in Australia, New Zealand and South Africa would be different; of course, many of the constellations are visible from all parts of the world (Orion, for example), but people who live in the south lack the Great Bear, just as Britons and New Yorkers can never see the Southern Cross.

An article on the southern stars was given in the *1972 Yearbook*, and the notes which follow here are intended only as a general guide. Details of eclipses and other phenomena are given in the monthly notes for southern observers as well as for northern.

In summer (December) evenings Orion is splendid in the north-east; Sirius shines brilliantly, and Canopus is high up, seeming almost to rival Sirius in glory. Achernar, the first-magnitude leader of Eridanus, is almost overhead; to the north-west the Square of Pegasus may be made out, and Fomalhaut is higher in the north-west, appearing much more striking than Europeans can realize. Crux Australis, the Southern Cross, is low in the south – at least from South Africa and most of Australia; from New Zealand it always maintains a respectable altitude. The Clouds of Magellan are high, and so is the characteristic constellation of Grus, the Crane.

In autumn (March) evenings Orion is still very evident, and Crux is becoming prominent in the south-east. South Africans and most Australians – though not New Zealanders – will see Capella shining low over the northern horizon; Fomalhaut is nearing the horizon in the south-west. By winter (June) evenings Crux is near the zenith, with its two glorious 'pointers', Alpha and Beta Centauri; Orion has gone and Achernar is low, while Antares in the Scorpion is climbing in the south-east, and Leo and Virgo are quite high in the northern part of the sky. Sirius is low, but Canopus is still dominant, south-west of the zenith, together with the gloriously rich region of Carina, the

Keel of the now-dismembered Ship Argo. In the late winter months and in early spring (September), the Scorpion is magnificent, and near the zenith. Crux is now in the south-west, but still conspicuous. Later in the evening the triangle comprising Vega, Altair, and Deneb may be seen in the north, though only Altair is reasonably high.



Eclipses in 1974

In 1974 there will be four eclipses, two of the Sun and two of the Moon.

(1) *A partial eclipse of the Moon* on 4 June will be visible in south-west Asia, Africa, and Europe. The eclipse begins at 20^h 39^m G.M.T. and reaches a maximum at 22^h 16^m, when 83 per cent of the Moon's disk will be covered with the Earth's shadow. The eclipse ends at 1^h 08^m on 5 June.

(2) *A total eclipse of the Sun* on 20 June will be visible only in the southern hemisphere. The path of totality lies wholly in the Indian Ocean, but just touches the extreme south-west coast of Western Australia. A partial eclipse will be seen throughout Australia. At Perth, which lies north of the track of totality, the eclipse begins at 3^h 48^m, and 96 per cent of the Sun will be covered by the Moon at the maximum phase at 5^h 16^m G.M.T.

(3) *A total eclipse of the Moon* on 29 November will be visible in Asia, Australia, and New Zealand. In the British Isles only the end of the eclipse will be visible, the total phase ending at 15^h 52^m, and the shadow of the Earth passing off the Moon's disk at 16^h 58^m.

(4) *A partial eclipse of the Sun* on 13 December will be visible in North and Central America and in the Atlantic Ocean. In the extreme south-west of Ireland, the eclipse begins at about 16^h 16^m, shortly before local sunset.

Occultations in 1974

In the course of its journey round the sky each month, the Moon passes in front of all the stars in its path and the timing of these occultations is useful in fixing the position and motion of the Moon. The Moon's orbit is tilted at more than five degrees to the ecliptic, but it is not fixed in space. It twists steadily westwards at a rate of about twenty degrees a year, a complete revolution taking 18·6 years, during which time all the stars that lie within about six and a half degrees of the ecliptic will be occulted. The occultations of any one star continue month after month until the Moon's path has twisted away from the star but only a few of these occultations will be visible at any one place in hours of darkness.

There are only four first magnitude stars that can be occulted by the Moon; these are Regulus, Aldebaran, Spica and Antares, but none of these stars will be occulted in 1974. The planets Mercury, Venus, Mars, and Saturn will be occulted during the year, and of these events, two occultations of Saturn and one of Venus will be visible in the British Isles. The occultations of Venus on 17 July and of Saturn on 3 February will take place in daylight hours, but that of Saturn on 2 March should be easily observed. On this occasion Saturn is predicted to disappear behind the Moon on 2 March at 23^h 48^m and reappear on 3 March at 0^h 44^m, the Moon being then one day past the First Quarter.

Comets in 1974

The appearance of a bright comet is a rare event which can never be predicted in advance, because this class of object travels round the Sun in an enormous orbit with a period which may well be many thousands of years. There are therefore no records of the previous appearances of these bodies, and we are unable to follow their wanderings through space.

Comets of short period, on the other hand, return at regular intervals, and attract a good deal of attention from astronomers. Unfortunately they are all faint objects, and are recovered and followed by photographic methods using large telescopes. Most of these short-period comets travel in orbits of small inclination which reach out to the orbit of Jupiter, and it is this planet which is mainly responsible for the severe perturbations which many of these comets undergo. Unlike the planets, comets may be seen in any part of the sky, but since their distances from the Earth are similar to those of the planets their apparent movements in the sky are also somewhat similar, and some of them may be followed for long periods of time.

The number of comets under observation in any one year varies considerably, but is much greater than is generally supposed. Thus 1970 created something of a record, since not only were 27 comets under observation, but three of these were naked-eye objects, while four others were easily visible in binoculars. No less than eleven periodic comets were recovered as a result of successful predictions, and of these two had not been seen since their discovery thirty years previously. The following table compares the numbers of newly discovered comets, successfully predicted returns, and comets still being followed from the previous year:

	1969	*1970*	*1971*
New discoveries	5	6	1
Predicted and recovered	4	11	5
Still under observation	9	10	14
Totals	18	27	20

The following short period comets are among those most likely to be recovered in 1974:

Comet Encke is expected to make its fiftieth return to perihelion in the spring of 1974, and this will be its fiftieth appearance since its discovery in 1786. The comet is named after the famous German mathematician who first computed its orbit, which has the very short period of 3·3 years.

Comet Reinmuth (2) was discovered in 1947 and was seen at each subsequent return. It has a period of 6·73 years and is expected at perihelion in May.

Comet Borrelly is also expected at perihelion in May. It was first seen in 1905, and had made eight appearances up to 1967, having been missed in 1939 and 1946. This comet has the high inclination of 31 degrees, with a period of 7 years.

Comet Finlay was discovered in 1886 and had made eight appearances when it returned in 1967. The comet has a period of 6·9 years, and only a very small inclination to the ecliptic.

Comet Wirtanen was first seen in 1947 and has been seen at each subsequent return. It has a period of 6·65 years and is expected at perihelion in August.

Comet Schwassman-Wachmann (2) was discovered in 1929 and has made seven appearances, the last being in 1968. This is a faint comet, having a period of 6·6 years and an orbit of small eccentricity. It is due to reach perihelion in September.

Comet Honda-Mrkos-Pajdusakova makes its return to the Sun at the end of 1974. Its triple name is due to its discovery in 1948 by three independent observers. Like Encke's comet it has a short period (5·2 years) and travels in a very eccentric orbit.

Comet Schwassmann-Wachmann (1) has a nearly circular orbit with a period of 16 years, which lies entirely between the orbits of Jupiter and Saturn. The motion of this comet is very much like that of a planet, and it is visible each year. It is remarkable for its sudden outbursts of brightness, which seem to have some connection with solar activity.

In addition to these periodical comets, the non-periodical comet Kohontek is expected to be a naked-eye object during the first few weeks of 1974.

Meteors in 1974

Meteors ('shooting stars') may be seen on any clear moonless night, but on certain nights of the year their number increases noticeably. This occurs when the Earth chances to intersect the orbit of a meteor swarm, which is a concentration of meteoric dust moving in an orbit around the Sun. Such an intersection can occur only at one particular time of year, but if the dust is spread out along the orbit, the resulting shower of meteors may last for several days. The word 'shower' must not be misinterpreted – only on very rare occasions have the meteors been so numerous as to resemble snowflakes falling.

The naked-eye study of meteors is quite a laborious task, but even a casual observer, watching for, say, ten minutes on an August night, may observe a number of Perseids. If their tracks are marked on a star map, and traced backwards, a number of them will be found to intersect in a point (or a small area of the sky) which marks the radiant of the shower. This gives the direction from which the meteors have come.

The following table gives some of the more easily observed showers with their radiants; the effect of moonlight in 1974 is indicated.

Limiting dates	*Shower*	*Maximum*	*R.A.*	*Dec.*	
Jan. 1-4	Quadrantids	Jan. 3	$15^h 28^m$	+ 50°	
April 20-22	Lyrids	April 21	$18^h 08^m$	+ 32°	
July 27-Aug. 17	Perseids	Aug. 12	$3^h 04^m$	+ 58°	
Oct. 15-25	Orionids	Oct. 21	$6^h 24^m$	+ 15°	
Oct. 26-Nov. 16	Taurids	Nov. 1	$3^h 36^m$	+ 14°	M
Nov. 15-17	Leonids	Nov. 17	$10^h 08^m$	+ 22°	
Dec. 9-14	Geminids	Dec. 14	$7^h 28^m$	+ 32°	
Dec. 17-24	Ursids	Dec. 22	$14^h 28^m$	+ 76°	

M = moonlight interferes

Minor Planets in 1974

Although there are many thousands of minor planets, only about 2,000 have well-determined orbits, and are listed in the catalogues. Of these, only the 'big four', Ceres, Pallas, Juno, and Vesta can reach any considerable brightness, and Vesta can occasionally be seen with the naked eye. This should be possible in 1974, when Vesta comes to opposition on 31 March, its magnitude then being +5·9 (see note and diagram on page 65). The magnitudes of the other three at opposition are: Ceres +7·3 on 1 September. Pallas +9·2 on 24 July, and Juno +8·1 on 5 September.

Some Events in 1975

ECLIPSES

In 1975 there will be four eclipses, two of the Sun and two of the Moon.

11 May – a partial eclipse of the Sun, visible in West Africa and Europe.

25 May – a total eclipse of the Moon, visible in Europe, Africa, and America.

3 November – a partial eclipse of the Sun, visible in Antarctica.

18 November – a total eclipse of the Moon, visible in Asia, Europe, Africa and America.

THE PLANETS

Mercury will be seen most easily as an evening star at greatest eastern elongation on 23 January and 17 May, and as a morning star at western elongation on 25 October.

Venus will be a brilliant object in the spring months as an evening star. Greatest eastern elongation is on 18 June, and greatest elongation west on 7 November.

Mars will be a morning star for most of the year, coming to opposition in Taurus on 15 December.

Jupiter is in conjunction on 22 March, and will be at opposition in Pisces on 13 October.

Saturn is at opposition on 6 January in Gemini, and in conjunction on 15 July.

Uranus is at opposition in Virgo on 21 April.

Neptune is at opposition on 1 June in Scorpius.

Pluto is at opposition on 29 March.

PART TWO

Article Section

Uranus – the amateurs' planet

GILBERT E. SATTERTHWAITE

Uranus – the first discovered planet – is so far away that it is only just visible to the unaided eye as a very faint 'star', and needs an accurate chart for its identification. Even a telescope of quite large aperture reveals no surface detail, and Uranus is frequently dismissed as being of little interest, especially by the amateur astronomer.

In fact Uranus is a fascinating planet, and many of the historical observations can be re-created by the amateur observer, who will gain much enjoyment in the process. It is worth recalling that Uranus was originally discovered by one of the greatest amateur observers of all time – Sir William Herschel – and that he was using only a six-inch reflector of his own construction. At the time of the discovery Herschel earned his living as a musician and teacher of music, and was in every sense an amateur. Following the discovery, however, he was granted a royal stipend by King George III, and so must presumably be deemed to have forfeited his amateur status!

Many of the known facts about the Uranian system, as well as the planet itself and four of its five satellites, were discovered by amateurs.

Discovery

The discovery of Uranus was no fortuitous event, as Herschel himself makes clear in a letter to the President of the Royal Society, Sir Joseph Banks:

> 'This new star could not have been found out even with the best telescopes had I not undertaken to examine every

> star in the heav'ns including such as are telescopic, to the amount of at least 8 or 10 thousand, I found it at the end of my second review after a number of observations not less than 15 thousand; so that the discovery cannot be said to be owing to chance only it being almost impossible that such a star should escape my notice. . . .'

The epoch-making discovery was made on Tuesday 13 March, 1781, from Bath where Herschel had lived since 1766. He was using a 7-foot reflector of 6·2 inches (16 cm) aperture, and an eyepiece giving a power of ×227, and was examining part of the constellation Taurus for double stars. When he came to scan an area close to the Taurus–Gemini border inside the triangle formed by the stars β Tauri, ζ Tauri and η Geminorum, Herschel saw an object a little less than 1° south of the fifth-magnitude star 132 Tauri. The image of the object was noticeably larger than those of the nearby stars and Herschel suspected that it might be a comet. He therefore examined it with higher power eyepieces, which produced larger but fainter images, thus confirming its non-stellar nature. Thus Herschel was convinced that he had discovered a new member of the solar system, even before obtaining the further observations necessary to reveal its orbital motion. It is not surprising that he thought it to be a comet, for no-one had ever discovered a new planet. The five planets already known were all bright naked-eye objects that had been known from antiquity.

The first person to decide the true nature of the new discovery appears to have been the Astronomer Royal, Nevil Maskelyne, who had had the new planet's position observed regularly at the Royal Observatory, Greenwich, since receiving Herschel's notification of its discovery. The first published observation of Uranus at Greenwich was made on 1 April, 1781. On 23 April Maskelyne wrote to Herschel:

> 'It is as likely to be a regular planet moving in an orbit nearly circular round the sun as a comet moving in a very excentric ellipsis. I have not yet seen any coma or tail to it.'

One of the foremost astronomers to study the new planet was J. E. Bode (remembered for 'Bode's Law'). Towards the end of 1781 Bode published an analysis of observations of the new planet made between April and September of that year, and stated that the observations showed the object to be a 'hitherto unknown distant planet of the solar system 19 times farther than the Earth and almost as far again as Saturn from the Sun, taking 82 years to revolve around it.' (Modern determinations of these figures are 19·181 and 84·01 years.)

Diameter

Once the nature of the new planet was established Herschel naturally made extended efforts to measure its diameter. From a series of measurements made between 1781 November and 1782 November he obtained values for the angular diameter ranging from 3·5″ to 5·8″, with an average value of 4·18″. By 1788 Herschel had completed a detailed analysis and published his planet's mean apparent diameter as 3·90554″, equivalent to a diameter of 34,217 miles (54,980 kilometres). The value adopted today (for mean opposition distance) is 3·57″, equivalent to a mean equatorial diameter of 29,268 miles (47,100 km).

Name

It was also Bode who suggested the name of the new planet, but it was not universally adopted for some time. Herschel himself called it *Georgium Sidus* to mark his appreciation of the patronage he now received from George III, and it was listed as the Georgian Planet in the British *Nautical Almanac* until 1850. Other names had been proposed – Herschel, Neptune, Minerva, Cybele, etc. – but eventually Bode's suggestion was adopted and the planet named after Uranus, father of Saturn and grandfather of Jupiter.

First Satellites

In 1787, just six years after discovering the planet, Herschel discovered its two largest satellites with the aid of his 20-foot reflector, aperture 18·7 in. (47 cm). Herschel recorded the discovery as follows:

> '. . . The 11th of January, therefore, in the course of my general review of the heavens, I selected a *sweep* which led to the Georgian planet; and, while it passed the meridian, I perceived near its disk, and within a few of its diameters, some very faint stars whose places I noted with great care.
>
> 'The next day, when the planet returned to the meridian, I looked with a most scrutinizing eye for my small stars, and perceived that two of them were missing. Had I been less acquainted with optical deceptions, I should immediately have announced the existence of one or more satellites to our new planet; but it was necessary that I should have no doubts. The least haziness, otherwise imperceptible, may often obscure small stars; and I judged, therefore, that nothing less than a series of observations ought to satisfy me, in a case of this importance. . . .'

During the next month he studied the changing positions of these faint objects until, on 8 February, he was able to confirm the nature of one of them, the satellite we now know as Oberon, as follows:

> 'Accordingly I began to pursue this satellite on February the 7th, about six o'clock in the evening, and kept it in view till three in the morning on February the 8th; at which time, on account of the situation of my house, which intercepts a view of part of the ecliptic, I was obliged to give over the chace: and during those nine hours I saw this satellite faithfully attend its primary planet, and at the same time keep on, in its own course, by describing a considerable arch of its proper orbit.'

On 11 February he was able to satisfy himself that both of the two faint 'stars' he had been following since 11 January were true satellites of his planet:

> '. . . in order to put my theory of these two satellites to a trial, I made a sketch on paper, to point out before-hand their situation with respect to the planet, and its parallel of declination. The long expected evening came on, and . . . it cleared up at last. And the heavens now displayed the original of my drawing, by shewing, in the situation I had delineated them, *The Georgian Planet attended by two Satellites.* I confess that this scene appeared to me with additional beauty, as the little secondary planets seems to give a dignity to the primary one . . . For upwards of five hours I saw them go on together, each pursuing its own track; . . .'

Herschel wrote that he had not observed the satellites for long enough to determine their orbital periods accurately, but the disclaimer seems superfluous since he went on to suggest that: '. . . the first performs a synodical revolution in about eight days and three-quarters, and the second in nearly thirteen days and a half . . .': modern determinations are 8·71 days and 13·47 days respectively.

Herschel also stated that the orbits of the two satellites 'make a considerable angle with the ecliptic'.

(The extracts quoted here make interesting reading for observers of today. They are an object lesson in detailed reporting, and record observations carried out with praiseworthy thoroughness and diligence. It is comforting too to be reminded that even William Herschel was troubled with clouds and unfortunately situated buildings.)

Inclination of the Axis

Although he noted the high inclinations of the orbits of the satellites, Herschel does not seem to have deduced one of the most remarkable things about Uranus itself – the abnormally large inclination of its axis of rotation to the plane of its orbit – at least 82°, or more than three times the greatest inclination of any of the other planets known at the time, that of Saturn. The peculiarity of Uranus in this respect was recorded by Laplace in 1829, who stated:

> '. . . if the various satellites of a planet move in a plane greatly inclined to that of its orbit, it can be inferred that they are kept in that plane by the action of the planet's equator, and that therefore the planet rotates around an axis nearly perpendicular to the plane of the orbits of its satellites. It may therefore be affirmed that the planet Uranus, all of whose satellites move in a single plane almost perpendicular to the ecliptic, itself turns on an axis very little inclined to the ecliptic.'

Once the direction of rotation of the planet had been established, it became clear that the north pole was below the orbital plane, the tilt being not 82° but almost 98°, in fact 97° 53′.

Telescopic Appearance

The high inclination of Uranus leads to a remarkable change in the aspect of the planet as seen from Earth. Like those of the other planets, the axis of Uranus maintains a fixed direction in space (ignoring the very long-term effects of precession), so whilst at two points in its orbit its equator is presented towards the Earth, at two intermediate points we see it pole-on. In 1966 Uranus' equator was face-on to the Earth, so that its aspect was similar to that of Jupiter or Saturn, except that it appeared to be 'lying on its side'. Now, however, the north pole is turning towards the Earth, and will continue to do so until 1985 when the axis of the planet will be pointing almost directly towards us. The planet's aspect will then be a disk with the north pole almost at its centre. The pole will then turn away until in 2007 the planet is once again equator-on. As the sequence continues, the south pole will be presented towards us in 2030.

Oblateness

In 1778 the south pole of Uranus was presented Earthwards, so that when the planet was discovered three years later it still had almost a pole-on aspect. At such times the polar flattening is undetectable, and the observed disk of the planet appears almost circular. The oblateness of Uranus is about 1/14, and is best seen when the planet is equator-on to the Earth. This situation was first reached, following the planet's discovery, in 1798, and it is greatly to Herschel's credit that, having suspected a polar flattening since 1783, he was able to confirm it from observations made as early as 1792–4. The oblateness implies a rapidly rotating planet, which Herschel had postulated although he was not able to observe any surface markings and so determine the rotation period.

Surface Features and Rotation Period

The first reliable observations of surface markings of Uranus seem to have been made in 1870–72, half-a-century after Herschel's death, by W. Buffham using a 9-inch (22 cm) reflector. Uranus was at this time on the Gemini–Cancer border, having in 1865 completed one revolution of its orbit since discovery. At the time the south polar region would have been visible to one side of the disk, with the equatorial region running down the other. Buffham observed some dark spots and the lighter streak of the planet's equatorial zone; he detected their movement due to the rotation of the planet and suggested very tentatively a rotation period of about 12 hours.

A number of observers studied Uranus during the 1880s, notably G. V. Schiaparelli, but it was C. A. Young of Princeton who, in 1883, was first able to state, with reasonable certainty, that the planet had a bright equatorial zone bordered by parallel dusky equatorial belts, similar to those of Jupiter and Saturn. Young was using a 23-inch (58 cm) refractor. His observations were confirmed by numerous observers during the following few years, notably E. E. Barnard at the Lick Observatory, California, the brothers Henry of the Paris Observatory, and A. Henderson of Liverpool, but such are the difficulties of detecting surface features on the planet that they were able to add little.

Many of the earlier observers had suspected that the polar regions of Uranus were darker than the rest of the disk: this was confirmed by later observers using better instruments, particularly R. L. Waterfield, W. H. Steavenson, and M. B. B. Heath in England, G. Fournier and E. M. Antoniadi in France – the latter using the 33-in. (83 cm) refractor of the Meudon Observatory.

Improved observations of the disk markings also allowed the rotation period to be determined with some accuracy – the correct value of 10·82 hours being rather shorter than Buffham's first, very tentative, estimate. This rotation period was obtained both from observations of surface features and from photometric observations made at the Harvard College Observatory.

Spectrum and Constitution

Broad absorption bands in the spectrum of Uranus were discovered by both the pioneers of astronomical spectroscopy, Father Angelo Secchi in Italy and the great English amateur observer William Huggins. Infrared spectra obtained by V. M. Slipher at the Lowell Observatory, Arizona, in 1902–9 also showed broad absorption bands, and in 1932 Rupert Wildt published his classic paper analysing the spectra of the four giant planets and suggesting that the bands were due to methane. By 1934 his ideas had been completely vindicated by A. Adel and V. M. Slipher. Wildt proposed a model constitution for Uranus comprising a rocky core 7,000 miles (11,260 km) in radius, surrounded by an ice layer 6,000 miles (9,650 km) deep and a gaseous 'atmosphere' 3,000 miles (4,830 km) deep. During the last two decades, however, this concept has been rejected in favour of a gaseous constitution for the planet, as postulated by W. H. Ramsey. Uranus is denser than Jupiter and Saturn, however, and probably contains much less hydrogen and helium in its make-up. Ramsey suggested that its main constituents were probably water, methane, and ammonia.

Additional Satellites

Another great amateur planetary observer, William Lassell, discovered two further satellites of Uranus in 1851 October. Lassell was observing in Liverpool with his 24-in. (60 cm) reflector; the new satellites, Ariel and Umbriel, are much closer to the parent planet than Titania and Oberon, and Lassell showed that they were so close that they would have been beyond the limits of Herschel's telescope.

The fifth satellite, Miranda, is the only one to have been discovered by a professional astronomer, and the only one discovered photographically. It was found by G. P. Kuiper on a plate exposed on 16 February, 1948, with the 82-in. (208 cm) reflector of the McDonald Observatory, Texas.

Conclusion

In this brief paper I have tried to convey something of the fascinating history of Uranus as an object for study, in the hope that others will be persuaded to follow in the steps of William Herschel and study this interesting planet themselves. Those who do will find it both instructive and enjoyable, despite the difficulties involved.

Pioneer 10 – the first probe to Jupiter

H. G. MILES

Anyone can be excused for not being familiar with all the code names given to the various space activities and, at first, one could ask why the name *Pioneer* had been used for a probe to the largest planet when all previous American planetary probes have been under the name *Mariner*. *Pioneer* was used originally for the unsuccessful lunar probes way back in the early days of the space age, but the information sent back by them on the region between the Earth and Moon will ensure their place in the history books. They provided much of the data which led to the discovery of the outer radiation belt. *Pioneers 6, 7, 8*, and *9* have successfully followed on the theme of studying interplanetary space. The tenth of the series, launched on 3 March, 1972, was designed to explore the interplanetary regions outside that of the Earth and in fact to regions beyond the orbit of Jupiter. The opportunity of studying Jupiter was not overlooked and so one can consider *Pioneer 10* either as a Jupiter probe or an interplanetary probe. In fact it is the first of a series of Jupiter fly-by missions.

Jupiter, the largest of the planets, is a world entirely different from Venus and Mars, the targets for earlier space probes. Although it has been studied intensively by Earth-based astronomers, and considerable observational material is at hand, the structure of the planet is little understood. One is able to observe only the upper layers of the cloud surface which appear as a series of light and dark bands. On one of these is the Great Red Spot, a feature which dominates that region of the planet. Some features, of which the Red Spot is one, are virtually permanent members of the surface markings, but others are relatively short lived. From observations of the markings, it is found that the planet rotates at a very high speed, in just under 10 hours, an extraordinarily short time when one considers that Jupiter is more than 300 times more massive than the Earth.

The atmosphere of the planet contains hydrogen, helium, methane, and ammonia. Although the outer regions are at a very low temperature, the inner regions may be very hot. It is known that the planet radiates more heat than it receives from the Sun and this suggests that heat-producing processes exist in the interior. It is a powerful transmitter of radio signals, a fact that has interested the radio astronomer for a long time. Many theories have been put forward to explain this radiation and also the structure of the planet but so far, no one theory has provided a satisfactory answer to the many puzzling observational facts.

The satellite system governed by Jupiter is also of great interest. Of the four major satellites, three are larger than our own Moon, the other being only a fraction smaller. The largest, Ganymede, has a diameter greater than the planet Mercury! Io, the innermost of the four, has frequently been suspected of influencing the radio emission from the planet.

Enough has been said to show that Jupiter is a target of great interest, and one wonders whether our present views on the planet will be drastically modified in the same way as our ideas on Mars and Venus were after the successful American and Soviet probes had reached these planets.

Pioneer 10 weighs 259 kg and is roughly hexagonal in shape. One small unit houses the sub-systems and the electronics and another small unit attached to one side houses the electronics required for the experiments. Normally, for interplanetary probes, power has been provided by batteries recharged by solar cells, but this system was considered unsatisfactory for journeys of the type which would take the probe to the outer regions of the solar system. At a distance of the orbit of Jupiter, the power required to recharge the batteries using solar cells would necessitate having solar panels larger than a football field, a rather impractical proposition. It was therefore decided to use atomic power. Four SNAP-19 radioisotope thermoelectric generators (RTG), mounted in pairs, are placed at the ends of two 2·75-metre-long booms so as to reduce to an acceptable minimum the risk of neutron radiation effects on the experiments on board the spacecraft. The system is capable of providing 155 watts of power at launch, this value falling to 140 watts after about 18 months, i.e. when the probe reaches the orbit of Jupiter, and to 100 watts after 5 years. The RTGs are similar to those used on the *Nimbus* meteorological satellites.

Orientation of the spacecraft is maintained by spin stabilizing at 4·8 revolutions per minute about the main axis of the high gain antenna, 2·74 metres in diameter. The probe's velocity and distance are continually monitored by Earth using the Doppler shift on the telemetry signals and the antenna is kept pointing towards the Earth. This Earth alignment is achieved using gas jets mounted on opposite sides of the antenna. Mid-course corrections were carried out with these in conjunction with liquid hydrazine rockets mounted centrally. For the space orientation, sun sensors were used together with a sensor designed to fix on the star Canopus, as has been the customary practice for the Martian probes.

Possibly one of the biggest problems is the transmitting of instructions from Earth and the receiving of signals from the spacecraft. Radio messages, travelling at the speed of light, will take 45 minutes to reach the probe when it is in the vicinity of Jupiter, and one has to wait another 45 minutes to see if the signal arrived safely. This obviously demands precisely planned command operations. Although capable of storing up to five commands, *Pioneer* is controlled mainly by direct command from Earth. Over such vast distances, the fall-off of signal strength is worthy of comment. A signal initially with a power of 8 watts will fall to 1/100,000,000,000,000,000 watt, such a small quantity that, if collected for 19 million years would light a 7·5 watt bulb for a thousandth of a second. This weak signal is collected by the Deep Space Network dish (64 metres diameter) at Goldstone, Arizona, and six others situated in Africa and Australia. Using these, it is possible to keep the spacecraft under constant surveillance.

Pioneer 10 will be the first probe to escape from the Solar System. This raises the possibility, admitted exceedingly remote, that some time in the future the probe may be located by some intelligent form from a distant stellar system. It was therefore decided that a plaque giving some information of its origin would be attached to the antenna. The plaque measured approximately 15 × 23 cm and was made of gold anodized aluminium plate. The position chosen was such that it would be shielded from erosion by interstellar dust. On the left of the plate were radiating lines representing the positions of 14 pulsars, arranged to indicate the Sun as the home star of the launching civilization. At the end of each line were marks representing the frequencies of the pulsars at the time of launch, relative to that of the hydrogen atom, shown in the upper left-hand corner. The regular decrease in the frequency of the pulsar will enable these 'new' people to tell when the probe was launched. On the right-hand side of the plaque are outline figures of man and woman, the size of these being referred, using the binary system, to the hydrogen wavelength. Along the bottom of the plaque is a diagram giving the Sun and the planets in order together with a line showing the probe trajectory swinging away from the Earth and passing Mars and Jupiter. The rings of Saturn provide an unambiguous interpretation of the diagram.

Although one important aspect of the flight is to develop the technology required for deep space missions, the thirteen experiments are perhaps, at least to the astronomer, of greater importance. They are designed to provide, at first hand, the conditions existing in the outer regions of the Solar System and the first close-up pictures of Jupiter. A three-axis helium vector magnetometer, mounted at the end of a 6·5-metre boom, will provide information on the inter-planetary magnetic field, the solar wind interaction with Jupiter, the magnetic field of the planet, and the effect of the satellites on this magnetic field. The system is capable of measuring fields as low as 10^{-7} gauss. A further important aspect is the proposed mapping of the heliosphere boundary in any one of eight ranges between 2·5 and 1·4 gauss.

The plasma analyser will supplement the information on the magnetic fields to give a general understanding of the interaction of the solar wind with the planet. It consists of both a high and low resolution analyser. The former is capable of measuring solar-emitted ion flux and velocity between 100 and 18000eV, whilst the latter, using 5 electrometers, is limited to measuring solar ions in the 100-8000 eV range and electrons in the 1-500 eV range. From this information it will be possible to map the solar wind density and energy and also the heliosphere boundary. The composition and density of charged particles will be investigated by a further series of experiments. These include the recording of particles in the 1-500 MeV range, the density and motion of helium nuclei and protons and the concentration of solar and galactic cosmic radiation, together with the magnetic field effects on these particles. The charged particle composition instrument is capable of identifying the eight elements up to oxygen and, as far as hydrogen and helium are concerned, identifying the separate isotopes. A further experiment will study the composition and energy of the Jovian radiation belts and their relationships with the radio emission from the planet.

Mounted below the equipment compartment are four non-imaging telescopes, each having an 8°-field of view and consisting of a 20-cm primary mirror, a 8·4-cm secondary mirror, and a photo multiplier, designed to measure the Zodiacal Light and solar reflections from interplanetary material. These will provide information for those interested in cometary, meteoroid, and asteroid studies. The velocity and range of the detected particles will be determined by the character of the pulses created by the photomultipliers as the object passes successively through the overlapping field of view of each telescope. The character of the micrometeor impacts during the trans-Jupiter coast will be studied using thirteen panels each 20 × 30 cm and containing eighteen pressure cells filled with argon-nitrogen gas. The penetration achieved by each impact is recorded.

An ultraviolet photometer working at 1216 and 584 Ångströms will measure the scattering effect of Jupiter's atmosphere on solar U-V radiation, the density of atoms of hydrogen and helium in the Jovian atmosphere, as well as the concentration of interplanetary hydrogen and dust. An infrared radiometer, incorporating a 7-cm Cassegrain telescope working in two channels, 14-25 and 29-56 microns, will measure the infrared energy flux, its distribution, the thermal distribution, and chemical composition of the atmosphere.

Normal photography of the surface of the planet, as carried out by the *Mariner* probes to Mars, is not being undertaken because of the technical difficulties and also the fact that the visible surface of the planet consists of clouds. However, by using the fact that the probe is spinning about the main axis, scans of the planet's clouds in strips 0°·03 wide will be attempted. The resolution obtainable will be better than that achievable by Earth-based telescopes. Of particular interest will be the areas near to the terminator, a region not seen from the Earth. These strips will be curved and hence require computer processing to compensate for the spacecraft velocity and spin, as well as the rotation of Jupiter. The light from the planet is first split into two beams according to the polarization levels and each of these into two further beams by blue and red filters. The emerging light is then converted into electric pulses and the information transmitted back to Earth in digital form.

It is interesting to point out that all the equipment for the above experiments weighs only 30 kg. Two further experiments, not requiring equipment on board the probe complete the planned study of the planet. The S-band occultation experiment, so successful in the case of the Mars probes, will analyse the behaviour of the telemetry as the probe passes behind Jupiter after closest approach. This could provide information on Jupiter's ionosphere, atmospheric pressure, a refractive index profile, ionospheric electron density, atmospheric hydrogen to helium ratio, absorption profile, and ammonia abundance. If, in addition, it travels behind Io, it will provide information on a possible atmosphere of the satellite and also a precise value for its diameter.

A study of the path taken by the probe as it passes the planet, using Doppler shifts of the signals, will provide more accurate values for the mass of the planet and its satellites and also the degree of flattening of the planet's polar diameter. It will also provide a more precise value for the distance of the planet from the Earth.

The probe was successfully launched on 3 March, 1972, from Cape Kennedy (now again known by its former name of Cape Canaveral), on a journey which will carry it past Jupiter on 3 December, 1973. No attempt was made to place the probe into Earth orbit before despatching it to Jupiter. It was fired directly into a Jupiter insertion trajectory using an Atlas-Centaur rocket, which accelerated to 51,000 km/hr, the fastest speed so far for a space probe. It crossed the orbit of the Moon in 11 hours after launch, the normal lunar probe taking about three days. The first mid-course correction was carried out on 7 March, 1972, and this produced a track which would ensure a successful pass of the planet, and a capability of achieving all the objectives except a passing behind Io. A second correction was made to the orbit on 24 March, 1972, this being designed to delay the arrival at the planet by 2½ hours. It enabled the fly-by to occur at a distance of 6,400 km and an opportunity to look at the Great Red Spot. By 25 May, it had crossed the orbit of Mars, having travelled 248 million kilometres and by early July had entered the asteroid belt. A third mid-course manœuvre was carried out on 19 September, with a result that the probe will reach Jupiter 17·2 minutes earlier. This was carried out to enable the spacecraft to be occulted by the satellite Io. The trajectory is therefore suitable for all the objectives to be met. At the time of writing (early January 1973) the spacecraft was still operating successfully as it approached the outer boundary of the asteroid belt.

Preliminary results of conditions in interplanetary space are of considerable interest. By 5 May, 1972, the micrometeorite detector had reported that 41 of the pressure cells had been penetrated, double the rate expected, whilst the meteoroid detector telescope system had observed 20 objects, again greater than predicted. The rate of the micrometeoroid detector impacts fell as the probe traversed the orbit of Mars and increased again when clear of the Martian orbit. Six impacts were recorded between 19-26 June, 1972. As at 20 October 20, 1972, 83 penetrations of the 234 cells had been recorded. Apart from the drop as the orbit of Mars was crossed, there has been a fairly constant count, indicating that these very small particles are not associated with the asteroid belt, but with cometary débris. By the beginning of October the number of larger particles recorded had increased to 100 and by November the value had increased to about 200. Analysis of two of the objects seen early in the flight showed that the particles were travelling in a direct elliptical heliocentric orbit with a relatively low inclination to the ecliptic.

The imaging photopolarimeter has been used successfully in measuring light intensity and polarization levels, and on 24 March, 1972, indicated that the relative brightness distribution of the Gegenschein was similar to that obtained from Earth-based observations but the brightness was between 5-10 per cent. greater than the Zodiacal Light background level, indicating that the Gegenschein is associated with Solar System dust and not with the Earth.

Some early results from the cosmic-ray experiment have shown that at regions beyond the Earth orbit, the Sun does not modify drastically the distribution of the cosmic-ray particles arriving from regions beyond the solar system.

If all goes well, it may be possible to follow the probe out to about the orbit of Uranus, about six years after passing

Jupiter. Although beyond the range for contact, it will then go on and eventually pass out of the Solar System and to a future unknown. According to a press report published in the United States, the probe will pass close to Aldebaran in about 1·7 million years time!

It is planned to send another probe to the planet in 1973 April, almost identical with the one launched earlier. The value of the results from the two spacecraft will be much greater than the results from the individual probes.

Date 1972	*Distance from Earth* (million km)	*Distance from Jupiter* (million km)	*Speed Relative to the Sun* (km sec)
Mar 14	8·8	799	—
Apr 5	26·2	729	—
May 5	50·5	651	—
May 25	75	610	30
Jun 26	138	531	25
Aug 1	227	468	23·6
Sep 2	324	420	22·2
Oct 2	423	377	20·0

Note added in press. The 1973 Pioneer has been successfully launched, and should by-pass Jupiter in the last days of 1974 or the first days of 1975.

Organic chemistry in the Galaxy

SIMON MITTON

During the past few years radio astronomers have made a series of fascinating discoveries about the gas found in our Galaxy. Many gas and dust clouds are scattered through the Milky Way, making them an important component of the interstellar medium, as the material between the stars is called. What has stirred up great interest is the identification of many different types of molecule in several of these clouds, particularly in the dark nebulæ that lie near the centre of the Galaxy. Complicated substances, such as formaldehyde and acetaldehyde, which may play a role in the synthesis of amino acids from simpler materials, have turned up in an abundance that has astonished most observers. These findings have encouraged chemists and biologists to see the entire Galaxy as a new kind of 'laboratory' in which they can witness chemical reactions under cosmic conditions. For astronomers the discovery of the molecular ingredients of interstellar soup has added a rich new dimension to the subject, because it is now feasible to observe the internal structure and motions of the clouds by looking at the radiations from their molecules. It is already clear that interstellar molecules will take their place alongside quasars and pulsars as great milestones in the history of radio astronomy.

The successful identification of molecules thousands of light years away in interstellar space depends critically on careful spectroscopy. Each molecule has associated with it a characteristic spectrum which corresponds to the particular frequencies of radiation that the molecule can emit or absorb. Just as an atom of the element sodium, for example, has the well-known

D line at 5898 Ångströms which can be seen in the spectrum of the Sun, so the various molecules also have their own set of 'fingerprints'. Most of the molecules found so far emit or absorb in the microwave region of the spectrum, which explains why radio astronomy has played such a prominent part in the recent identification of complex molecules. However, laboratory and theoretical studies have played an indispensable role in matching the spectra of line radiation from the gas clouds to specific molecules.

The gas between the stars is mainly composed of hydrogen and helium, with carbon, nitrogen, oxygen, and neon also present in small amounts. Astronomers at Mount Wilson found the first molecules in the 1930s when they detected in the spectra of bright stars absorption lines which are caused by CH and CN molecules. Radio astronomers first contributed in 1951 with the detection of the famous 21-centimetre emission line of atomic hydrogen. Over the last twenty years our knowledge of the spiral structure of the Galaxy has expanded enormously as astronomers have mapped out the distribution of the hydrogen gas in great detail. In this type of work the Doppler effect is a great asset: when a source of line radiation moves towards or away from an observer the wavelength of the radiation decreases or increases in proportion to the velocity. By careful measurement of the precise frequencies of the hydrogen emission and absorption the rotation rate of the galactic spiral arms has been established; similar work is important in unravelling the complex structure of galactic gas clouds.

The detection of absorption caused by the hydroxyl radical OH firmly established molecular astronomy in 1963. Soon this molecule acquired a reputation for mysteriousness: its line spectrum did not match the predictions of the theorists in every detail: the actual sources of emission were unbelievably tiny; and the radio waves themselves had quite amazing intensity. It just did not add up to simple physics. In fact the properties of the OH sources show that they are probably masers in deep space, capable of amplifying radio signals in a manner that is unknown at present. Indeed it was a complete surprise that masers, which have to be very carefully constructed in terrestrial laboratories, should exist naturally in the cosmic environment. For a while a handful of scientists joked that the masers could be gargantuan signalling devices constructed by a galactic supercivilization!

It is common to find water molecules in association with the celestial sources. Emission from the clouds of water vapour bears many similarities to OH radiation. For example, in both cases astronomers on different continents have had to pool their resources in order to measure the size of the emission regions. Radio telescopes in Europe and the U.S.A. have been linked together, by means of tape recorders, to form interferometers and thus achieve a large resolving power. Such efforts have shown that some galactic OH and H_2O clouds have diameters of only a few astronomical units, which is very small in relation to the great power of their radio emission. This combination of properties can only be accounted for as maser action with an amplification of perhaps 10,000 million.

By the end of 1968 the molecule seekers were down to real business, for it was then that Charles Townes and his colleagues at Berkeley detected interstellar ammonia (NH_3) at 1·26 centimetres wavelength. This announcement stirred other radio observers into action – like the planet hunters of the eighteenth and nineteenth centuries, the observers wanted to find undiscovered material in the heavens.

There are ammonia molecules embedded in the great complex of clouds at the centre of our Galaxy, and they show significant variation in their velocity and density over periods of a few weeks. This shows that the clouds are active, turbulent objects. An important property of ammonia is that fine detail in its spectrum changes with increasing temperature, and this could enable it to be used as a remote thermometer for probing the temperatures in clouds thousands of light years away.

Molecules that contain carbon, the organic molecules, broke on the scene in 1969, when L. Snyder, D. Buhl, B. Zuckerman, and P. Palmer identified formaldehyde (H_2CO). Several other carbon compounds have since added their names to the list of ingredients in the interstellar material: hydrogen cyanide, carbon monoxide, formic acid, methylacetylene, and cyanoacetylene to name but a few. Most of these are found principally in the galactic centre.

Formaldehyde molecules are of interest because they are only seen in absorption. This indicates that they are invariably colder than the surrounding material, implying that some unknown cooling process is chilling the formaldehyde. In some cases its temperature is only just above absolute zero, so that the interstellar refrigerators must be very efficient: The discovery of extremely cold formaldehyde is of interest for star formation for the following reason. When a cloud of gas contracts under the force of gravity to form a star, a lot of heat is generated, and this has to be released if the contraction is not to cease long before stellar densities are reached. Evidently the dark nebulæ of the Milky Way do have some way of achieving the necessary low temperatures, and although we do not know how they manage this, it would certainly encourage star birth.

Data on carbon monoxide and formaldehyde molecules have been particularly useful for detective work on the galactic centre. This murky region is hidden from even the largest optical telescopes by great swathes of dust. Yet to infrared eyes and radio telescopes the hub of the Milky Way is one of the brightest objects in the entire sky. Certainly there are strange affairs afoot in the galactic centre. Good evidence that gigantic explosions may take place in the galactic nucleus has come from a detailed study of the rich molecular clouds. Measurements of the Doppler shifts in the line frequencies have been translated into velocities in order to build up a picture of the traffic jam at the galactic nucleus.

Nicholas Scoville of Columbia University finds that much of the gas at the centre is concentrated into clouds, about 100 light years across, which contain up to one million solar masses. The clouds are moving at speeds exceeding 40 km/second in many cases, and their directions of motion do not match up with the normal rotation of the Galaxy. Scoville claims that the molecular line observations can most readily be interpreted as a rotating ring of clouds that is expanding away from the galactic nucleus. This swirling smoke-ring incorporates three million solar masses of gas and dust that appears to have been thrown out in an explosion which took place in the nucleus about a million years ago. Astronomically the most interesting aspect of this work on organic compounds is the demonstration that dense and massive clouds are found in the nucleus, and indeed throughout the rest of the Galaxy. The material which makes up the dark clouds is mainly of molecular form according to observations made so far.

A second important application for astrophysics of the new discoveries is in connection with isotopes. Take for example carbon, each atom of which contains six protons (positively charged particles) and a certain number of neutrons (neutral particles): carbon-12, which is common, has six neutrons whereas the rarer carbon-13 has seven neutrons. Now the cosmic ratio of carbon-12 to carbon-13 is of interest to theorists because they can predict the value that would be produced in accordance with different ideas on how the chemical elements have been synthesized from hydrogen, the lightest element. Radio astronomers have actually deduced the carbon-12/carbon-13 ratio at several places in the Galaxy from data on hydrogen cyanide and carbon monoxide emission spectra. Generally speaking, carbon-12 is much more abundant than carbon-13 in molecular clouds, in agreement with the value of 89 that we find for carbon on the Earth. However, the most popular theory of element building inside the stars (the so-called CNO cycle) favours a ratio of only 1 to 4. Thus, as far as the history of the interstellar gas is concerned, the molecules have pinpointed a shortfall in the theoretical ideas.

Finally, of course, the newly formed molecules are extremely relevant to discussions on the origin of life (self-replicating systems) in our Galaxy. The emergence of amino acids is one small step in the direction of proliferating macromolecules. None the less, Sidney Fox of Miami's Institute of Molecular Evolution has done much work on this basic problem. His research team has shown that many amino acids (the basic building-bricks of large organic molecules) can be synthesized from formaldehyde, cyanoacetylene, and ammonia, by the action of heat or ultraviolet radiation. Significantly these essential raw materials were among the first to turn up in the cosmic environment. The importance of the astronomical contribution is that it shows that the most essential materials, from which larger molecules might form, are present in great abundance in the gas clouds of the Galaxy. Amino acids have also been found in carbonaceous chondrite meteors, thus demonstrating that synthesis of the larger molecules does occur. Clearly there are many exciting possibilities for the future now that biologists, chemists, and astronomers have crossed the traditional boundaries of their subjects to join hands in space.

Magnetic Stars

V. BAROCAS

The terminology of modern astronomy appears to change very rapidly. In the last two or three decades new objects have been discovered in the sky which have necessitated the introduction of new names in the old science, but this is not the only cause of the origin of new terms. In many cases they are introduced following the observational confirmation of theories put forward by earlier astronomers. This has happened in the case of magnetic stars, for example. Although we have been using this term only since the late forties, nevertheless the possibility of the existence of such objects had been suggested half a century earlier.

The interest that astronomers show in the study of the Sun is not due only to its importance as the centre of the Solar System, but it is also due to the fact that the Sun is the nearest star to us and the only one which presents a disk. The various phenomena which occur on its surface and in its atmosphere can be studied in detail, and this enables us to learn more about the conditions prevailing generally on stars which are so far from us that they appear only as points of light.

It was towards the end of the last century that new techniques and new types of instruments led astronomers to concentrate on the study of the physical conditions of the Sun. By 1889 a suggestion had been put forward that the Sun might have a magnetic field, just like the Earth. Unfortunately at the time there were no means available to measure or even to detect such a magnetic field if it existed. As in so many other cases, it was a discovery made in physics, in the field of spectroscopy, which introduced a completely new approach to this problem and presented the astronomer with the possibility of applying this discovery, made in a terrestrial laboratory, to the study of the Sun and of the stars.

It was in 1896 at Leyden that a Dutch physicist named Zeeman made the very important discovery that a powerful external magnetic field produces the splitting up of a spectral line. Zeeman, in pursuing his investigations, discovered that when a source emitting a line spectrum is placed between the poles of a powerful electromagnet, the magnetic field splits the spectrum line into several components. The line is always split into a symmetrical pattern and the spacing of the components is proportional to the strength of the magnetic field. Therefore the measurement of the various components enabled an observer to determine the intensity of the magnetic field. In addition Zeeman discovered that the pattern depended on whether the light emitted were observed along the lines of force of the magnetic field or at right angles to it. In the first case instead of one line we have two lines of equal intensity displaced one towards the red and the other towards the violet. These lines are both circularly polarized and in opposite directions, while the central or original line which is normally observed when no magnetic field is present, has disappeared. The situation is different when we observe the light emitted at right angles to the lines of force of the magnetic field. In this case we have three lines all linearly polarized. The central line appears unshifted when compared with the original line but has an intensity which is twice that of either of the two side components which are of equal intensity (Figure 1). This is the simplest form of what is known as the Zeeman effect. Here, at last, was the possibility of determining whether the Sun had a general magnetic field or not.

It was not long before Hale and his colleagues began their investigations and they soon discovered the existence of large magnetic fields, of the order of several thousand gauss in sunspots. Further investigations revealed the existence of a

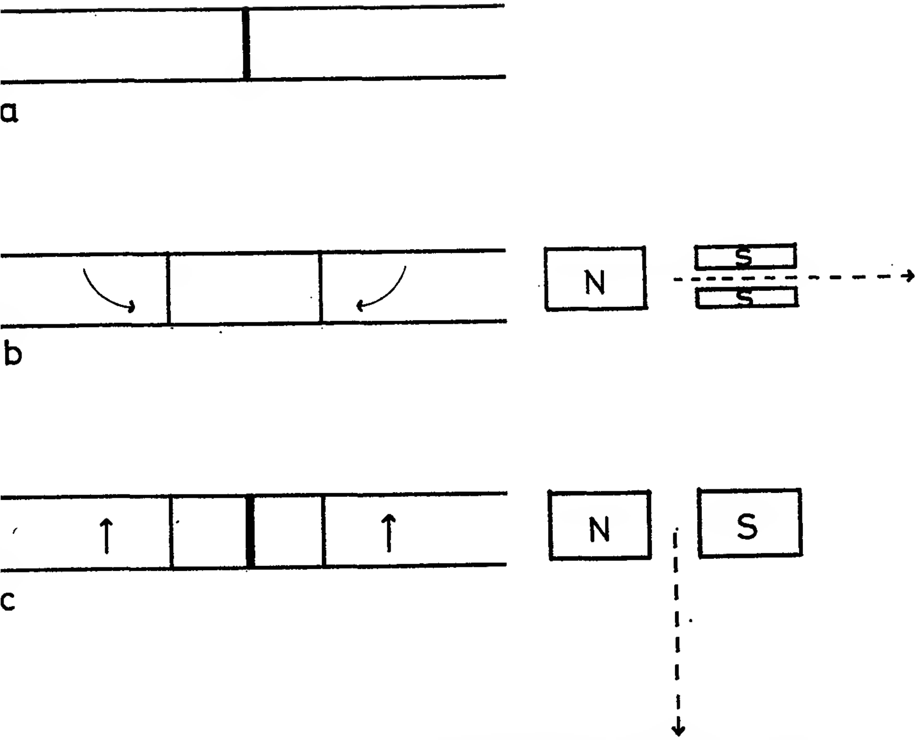


Fig. 1. **Zeeman effect: (a) No magnetic field; (b) Observations in the direction of the lines of force; (c) Observations at right angles to the lines of force.**

general magnetic field on the Sun which was of much smaller intensity. It was perhaps natural that Hale should wonder whether the stars also possessed a magnetic field and he decided to extend his investigations in this direction. To do this, however, much larger telescopes and special spectrographs were required. One of the difficulties, in fact, encountered in the observational work was that the displacement of the spectral lines which had to be measured was very small and it became obvious that spectrographs of very high dispersion were essential for this type of work. Today the dispersion of the spectrographs used for these investigations ranges between 2 and 10 Å/mm.

Hale died before stellar magnetic fields could be detected and the work was carried out successfully by Horace Babcock, who in 1946 showed that it was possible to detect and to measure magnetic fields in stars. The evidence of observations indicates that magnetic fields in stars are not uncommon, indeed probably a majority of stars have magnetic fields. Before studying the results of observations we ought to say something about the methods of observations and the types of instruments used in these investigations.

From what we have said about the Zeeman effect it must be obvious that the detection and measurement of a stellar magnetic field involves spectroscopic observations. Theoretical calculations show that the Zeeman shift is very small indeed. It becomes measurable in the case of magnetic fields of the order of 1000 gauss and when spectrographs are used which have a dispersion of the order of 5 Å/mm. If we assume that the strength of the magnetic field is a function of the rotational speed of the star then we can expect field strength of the order of a 1,000 gauss in several stars. In addition, if the star has a fast speed of rotation and its spectrum consists of very sharp lines, we can also assume that the polar axis is pointing towards us, otherwise instead of a sharp spectral line we would have a broad line due to rotational broadening. Bearing all these conditions in mind astronomers started observing early type stars which had very sharp spectral lines. Even so, the Zeeman shift expected was very small and the only way to detect the effect and hence the existence of the magnetic field, was to use a suitable analyser for the measurements. The method adopted therefore was to use a quarter-wave plate together with calcite in front of the slit of the spectrograph. The result of this is that the circular polarized components passing through the quarter-wave plate emerge as plane polarized beams which are then separated by the calcite.

One of the requirements for these observations, as already mentioned, is that the spectrograph should have a high dispersion and most of the work in this field has been done with a coudé spectrograph. This means that the light from the star undergoes a number of reflections in the telescope system before reaching the coudé focus. The polarizing effects of the mirror systems can, however, be compensated by various means before the light from the star reaches the analyser. The spectrograms obtained are a source of great information because in addition to the Zeeman effect which will tell us if the star has or has not a magnetic field, they also supply us with all the information that we generally can gather from the spectrum of a star, namely the intensity of the lines, the line profiles, and the radial velocity.

The observation of magnetic stars started less than thirty years ago, but the data which are accumulating begin to give us important information about this class of stars. About 350 stars have been studied and so far we have detailed information concerning the magnetic fields of about 90 of them. Of the remaining 260 stars observations seem to suggest that some of them have no magnetic field. The existence of a magnetic field seems probable in some of the others. The question which investigators naturally asked themselves was whether there existed any link between any particular spectral class of star and magnetic fields. The result of this investigation shows that the majority of the stars for which the existence of a magnetic field has been confirmed, belong to the peculiar A-type stars (Ap) but that all other spectral classes, ranging from B to M are also represented. To a certain extent this result is due to the actual selection of the stars which formed the sample studied. Many A stars were originally chosen because it was known that they had a very rapid rotation. The fact remains that there does not seem to be any special preference for any particular part of the H-R diagram.

Babcock has suggested a classification for the magnetic stars according to the characteristics of their magnetic field. He has taken as typical stars α^2 Canum Venaticorum, β Coronæ Borealis and γ Equulei and he has called the three classes accordingly α, β, γ.

In class α we have stars showing periodic variations of the magnetic field and an almost symmetrical reversal of the polarity. This class contains stars such as α^2 CVn and 53 Cam. Class β contains stars which show irregular variations of the intensity of the magnetic field and the reversal of polarity. Examples of this class are β CrB and 21 Per. Class γ contains stars which also have irregular field variations but have a constant polarity. γ Eql and 52 Her belong to this class.

A class δ was added to which were assigned stars which showed variations in the spectrum which did not appear to be related to the magnetic field.

A study of the stars belonging to the class α showed that there were variations in the intensity of the lines of their spectra which were related to changes in the magnetic field or, in other words, that they were variable as far as their spectrum was concerned. The largest variations in the intensity of the lines was found in particular for SrII and EuII while the Fe and Mn lines appeared to have only a negligible variation of intensity.

We have stated earlier on that the majority of the magnetic stars so far studied belong to the spectral class Ap. Peculiar stars are so called because of the abundance of certain elements, generally Si, Mn, and rare earths. The peculiarity lies in the fact that a particular star may at one time show a considerable abundance of one of these elements. After a time this abundance seems to disappear while the line of another element becomes very intense. It has been suggested that this variation in the spectrum is due to the fact that there are areas on the star which are particularly rich in one or other element and that these areas happen to be in the direction of the earth at different times. Even before the work on magnetic stars had begun it was known that as we proceed from class B8p to class F0p there appears to be an increase in the amount first of Mn and Si and finally of rare earths. Very recent investigations indicate that manganese stars generally have a low magnetic field strength. Efforts have been made to try to detect whether the content of the star was in any way related to the strength of the magnetic field. As a result of these studies it has been suggested that Mn stars have a magnetic field strength which is less than 400 gauss while Cr-Sr stars can have magnetic fields of the order of up to 200 gauss. Magnetic stars which have magnetic fields of up to 400 gauss are mainly Mn stars. For field strength from 400 to 700 gauss we have Mn and Cr-Sr stars with a preference for Mn at the lower values of these magnetic fields and for Cr at the higher ones. Above 700 gauss we then have mainly Cr-Sr stars.

So far we have discussed the spectra of magnetic stars but it is interesting to investigate whether the variation of the magnetic field is in any way accompanied by a variation of light. First of all it must be said that almost all the magnetic stars so far studied show a very small change in brightness, of the order of a few hundredths of a magnitude. The magnetic stars of class *α* which are mainly regular variables, have been mostly studied and the observations show that the minimum of the light curve occurs at the same time as the magnetic field reaches a maximum positive value (Figure 2). In many

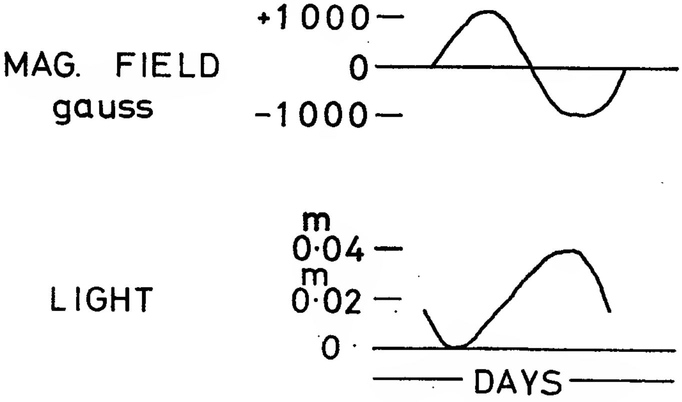


Fig. **2. Magnetic and light variation of a magnetic star.**

instances the light curve of these stars was already known and once the variations of the magnetic field were measured it became possible to compare the data with reference to the particular phase of the period of the star. However, many more observations are required to understand more fully the relation between light curve and magnetic field, and for this purpose it will be essential to obtain simultaneous photometric and magnetic observations so as to be able to determine how close is the correlation. What we have just said refers to magnetic stars of class α because unfortunately there are not enough observations available of stars of other classes to enable us to make further deductions. Observations made during the last twenty-five years have finally confirmed the fact that magnetic fields exist in stars. The measurement of the magnetic field and of its variations is a very delicate one and powerful instruments are required, but with the increase in the number of large telescopes perhaps, before long, more data will become available to give us a much clearer picture of the various phenomena related to magnetic stars.

At present efforts are being made to interpret some of the observed facts. Questions have still to be answered such as: why are the spectrum lines broader when the maximum of the magnetic field is sharper? – why the maxima of the magnetic field when it reaches opposite polarity have unequal width? – what is the meaning of the fact that so many of the magnetic stars appear to have a periodicity of one week? At the same time theoretical astronomers have been at work and have put forward ideas concerning physical models which could explain the star's magnetic field and its variations.

One of these models is the oblique rotator model. This assumes that the star is rotating and that the axis of rotation does not coincide with the magnetic axis (Figure 3). As the star rotates it presents to the observer on Earth different areas all having a different field strength and this could explain the periodic variation of the magnetic field. The variation in the spectrum could be explained if the distribution of the abund-

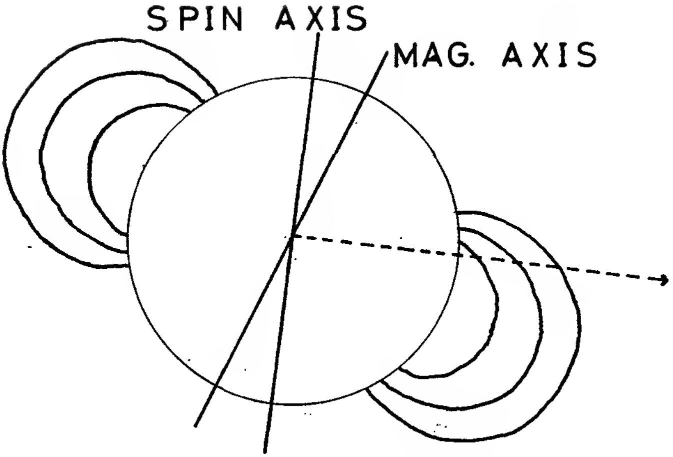


Fig. 3. The oblique rotator model.

ance of some elements were uneven and the rotation would bring in turn these areas towards the observer. The oblique rotator model would satisfy only some of the observations which have been obtained, but the greatest objection to it is that as far as the magnetic field is concerned it would imply that it is always fixed in relation to the star itself.

A second model which has received some attention is that of the magnetic oscillator. According to this theory the periodic changes of the magnetic field in a star are produced by oscillations of the body of the star. Yet another theory is based on the hydromagnetic cycle and is analogous to the solar cycle model.

The study of magnetic stars began in earnest less than twenty-five years ago and already considerable progress has been made. It is a very fascinating study which is giving the astrophysicist a new line of attack on many fundamental stellar problems and perhaps will help also to stimulate the study of many solar theories and phenomena, especially that of magnetic fields connected with solar flares.

Highly Reddened Stars

DAVID A. ALLEN

The question of why the sky is blue by day and black by night may not seem particularly relevant to the title above. It is certainly something that most of us take for granted. At night the sun is shining somewhere else, we naïvely argue, and hence all is dark; by day the sun lights up the sky and it is bright. But the sun is yellow – why, then, does it make the sky blue?

To answer this question we have to delve into physics. Theory tells us that small particles – grains of dust and smoke in particular – present more of a barrier to blue light than to red. Blue light, of course, is of shorter wavelength than red, so to a photon of blue light the microscopic particles that float lazily on the upper layers of our atmosphere seem bigger. Whereas red light gets by virtually unimpeded, much of the blue light bounces off the dust grains and is scattered to all directions. It is this scattered blue light that gives the sky its colour. In fact not all the short-wavelength radiation is scattered. Dust particles also absorb radiation, and the energy they therefore soak up goes into heating them. If a smoke cloud contains a lot of dust, very little light is scattered out of it, most being absorbed. Which is why smoke usually appears black rather than blue.

As the sun sinks into the evening sky, its light must traverse progressively longer paths through the atmosphere, therefore more and more of the blue light is scattered by dust grains. The results of this are twofold: firstly the sun appears red towards sunset; secondly it becomes fainter, because more of its total light has been removed. Whenever dust grains get in the line of sight, both *reddening* and *extinction* occur.

When the sun sets, it no longer illuminates the atmospheric dust and the sky darkens. It was Olbers who first pointed out the paradox which now bears his name – he demonstrated that, even after sunset, the sky should be extremely bright. Although distant stars and galaxies appear much fainter than do nearby ones, the rate at which they get fainter with distance is exactly balanced by their increasing numbers. If we add up the contributions from all the stars and galaxies from here to infinity, we find that they should make every patch of sky almost as bright as the sun's disk!

There are a number of reasons why Olbers' paradox is not applicable to our Universe, and one of these is that interstellar space is dirty. Our Galaxy contains dust enough to build several million stars. The dust lurks partly in big clouds and partly in an almost uniform smog throughout the galactic plane. It is the extinction produced by the interstellar material that causes distant stars to be fainter than they should be, and this nullifies Olbers' argument.

We have clear evidence of some of the great clouds of dust. A glance at the Milky Way in Cygnus reveals the famous Great Rift that splits the distant star clouds into two distinct sections – like some giant celestial clothes peg. In the southern skies the inky black Coal Sack is an even more prominent example. These dark clouds obscure, or at least considerably extinguish, the background stars. The presence of dust is also illustrated by the nebulæ around the stars in the Pleiades and elsewhere: these smaller clouds are seen by the radiation they scatter in our direction, and they consequently appear bluer than the stars that illuminate them.

Through the dark clouds we can see, faintly, the background stars which have been extinguished and reddened. We measure the amount they are extinguished in the visible (at a wavelength of about 5600 Å) in stellar magnitudes and write this A_v. Thus if a star suffers 1 magnitude of extinction, its radiation in the visible has been reduced by a factor of about 2·5. If

A_V is about 5 magnitudes, only one per cent. of its radiation gets through. If we also measure a given star in the blue (specifically at 4300 Å) we find it is extinguished more, by an amount A_B. The difference A_B-A_V is called the selective absorption or the reddening, and is usually written E_{B-V}. This quantity can be easily measured whereas A_V cannot, because we rarely know the distance of a reddened star, and hence how bright it would appear were it not obscured. Simple theory predicts that $E_{B-V}=\frac{1}{3}$ A_V if both are measured in magnitudes; empirical results suggest that the numerical factor may be smaller in selected parts of the sky.

Most stars are reddened by a few tenths of a magnitude, and values of E_{B-V} up to one or two magnitudes are not uncommon. A star as blue as Rigel would have the colour of Betelgeux if its E_{B-V} were somewhat in excess of two magnitudes, but it would then be so heavily extinguished as to be invisible to the unaided eye. There is a famous group of stars in the dark Cygnus rift which is known by the unpretentious name of Cygnus OB2 (formerly the VI Cygni association). This cluster of blue stars lies behind the dark clouds of obscuring dust that throng this part of the galactic plane. Over 1000 members of the cluster are known, the brightest being about 11th magnitude. All the stars are heavily reddened: for some E_{B-V} exceeds three magnitudes. Were there no dust in the way, this would be a most impressive star cluster, for several of its members would be the brightest stars in the constellation. But because of the great extinction, this cluster was not noticed until a few years ago. Some of its members claim the added distinction of being among the most reddened stars in the sky; indeed until 1971 the star unceremoniously referred to as No. 12 was *the* most heavily reddened known. Before 1971, then, the subject of this article ended just there.

How does one set about finding stars more reddened than those in Cygnus OB2? As the reddening increases, so does the extinction, therefore such stars appear very faint. It simply isn't practicable to examine every faint star in sufficient detail to establish whether it is heavily reddened. We need a better method.

The ease with which radiation passes through dust clouds increases the longer its wavelength. If we want to penetrate extremely thick curtains of dust, we must observe beyond the red end of the spectrum – in the infrared. The entire northern sky has been surveyed at two microns, a wavelength some four times as long as that of visible light. This survey was undertaken by Professors Neugebauer and Leighton of the California Institute of Technology, and was published in 1969. About as many stars as are visible to the unaided eye were recorded, and amongst these were some of the stars of Cygnus OB2. In addition to confirming our expectations of the behaviour of these stars, however, the 2μm survey further revealed that many cool red giant stars are surrounded by their own clouds of dust, and are correspondingly reddened. A great many heavily reddened stars were thus added to the list of those we had already recognized, but curiously enough none turned out to be more reddened than Cygnus OB2 No. 12. It seemed that an extinction of 10 magnitudes in the visible was about as high a figure as we would ever find for an individual star. Indeed it was believed that the total extinction between us and the very centre of our Galaxy is only about 35 magnitudes, and that nowhere is there dust enough to introduce more than 10 magnitudes of extinction between us and any star that is none the less near enough to be detected.

The realization that this was not the case, but that extremely dense dust clouds do exist quite local to the sun, resulted from radio astronomical observations. In 1971 a group led by Professor Thaddeus of Columbia University was engaged in an investigation of the distribution of various molecules (principally formaldehyde) in the Orion Nebula. Simple molecules emit (or absorb) at certain wavelengths in the millimetre region of the spectrum, much as the ions in stellar atmospheres give rise to bright or dark spectral lines at optical wavelengths. A study of these radio lines can tell us something about the conditions in which the molecules find themselves. In the case of the Orion Nebula, an unexpectedly high density (by astronomical standards) was deduced for the gas and dust clouds. When this was converted back to a value of the extinction, the staggering figure of 200 magnitudes was found for any object lying directly behind the Orion Nebula. Let us put this number into perspective by noting that one could hide the most luminous known quasar (or at any rate an equivalent source) at the centre of the Orion Nebula and it would be a hundred million million times too faint to be detected photographically by even the Palomar 200-inch telescope. On the other hand, this figure can itself be misleading: the dust and gas which would be collected by a sample 'core' of diameter one inch drilled right through the murkiest part of the Orion Nebula would weigh no more than one new penny!

Even before the 2-micron sky survey was completed, an infrared source was known to lie in the Orion Nebula, about one minute arc south of the famous Trepezium cluster of stars. This object was discovered by Eric Becklin and consequently bears his name. So red is Becklin's star that at wavelengths shorter than 1·5 μm it is quite undetectable, yet in the far infrared is one of the brightest stars in the constellation. It was only natural to assume that this object was intrinsically very red, and hence cool; Becklin's star was therefore widely believed to be a protostar – a compact cloud of gas and dust which was in the process of collapsing from part of the nebula to form a star, but which was not yet sufficiently hot and dense for nuclear reactions to have begun in its interior. This view was strengthened by the knowledge that in the Orion Nebula there are many extremely young stars which cannot long have been radiating as visible objects.

When the radio results were announced, Mike Penston, Harry Hyland, and I put forward the theory that Becklin's infrared source was really a normal star near the middle of the Orion Nebula experiencing very heavy reddening. We calculated that a normal star would appear this red if it had

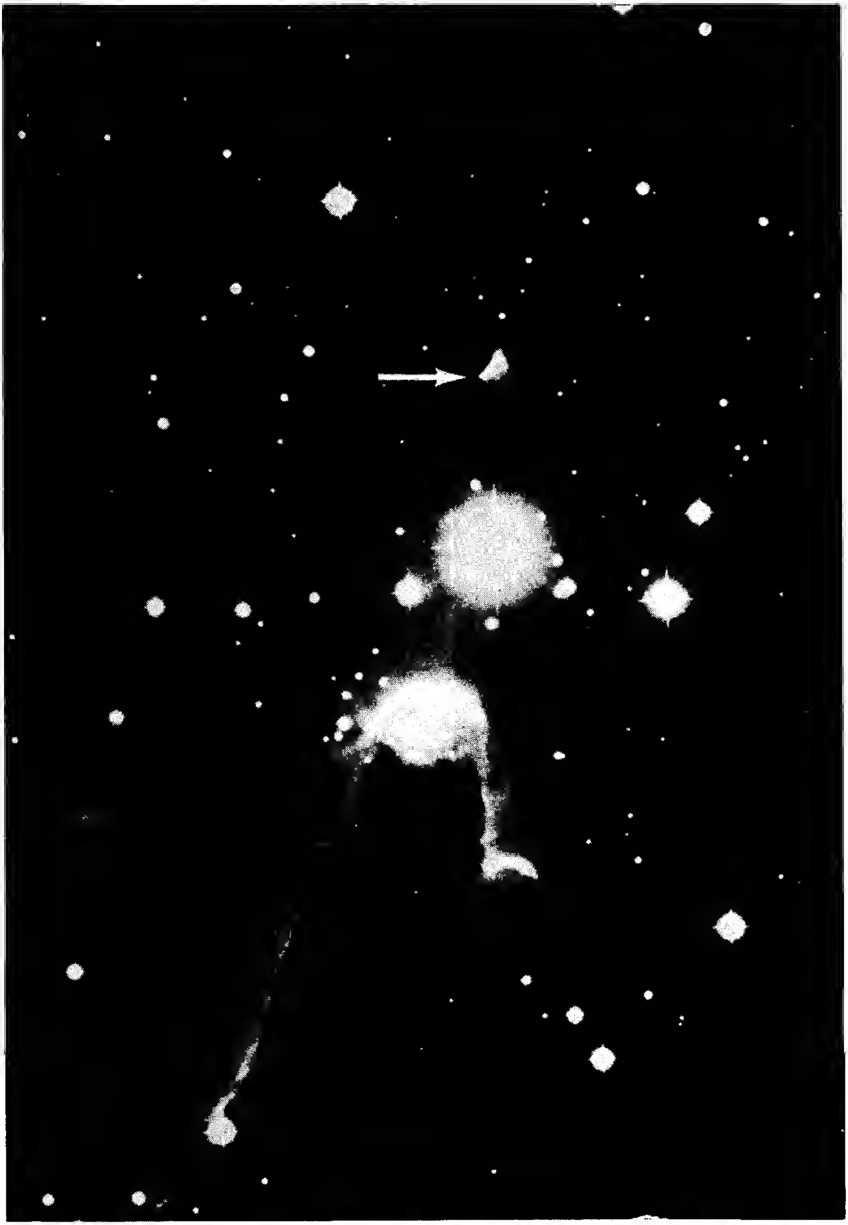


Fig. 1. The southern section of NGC 2264 photographed in the red Hα line of hydrogen. The position of the infrared source discovered by the author is marked by an arrow. Palomar 200-inch photograph courtesy of the Hale Observatories. (See page 163.)

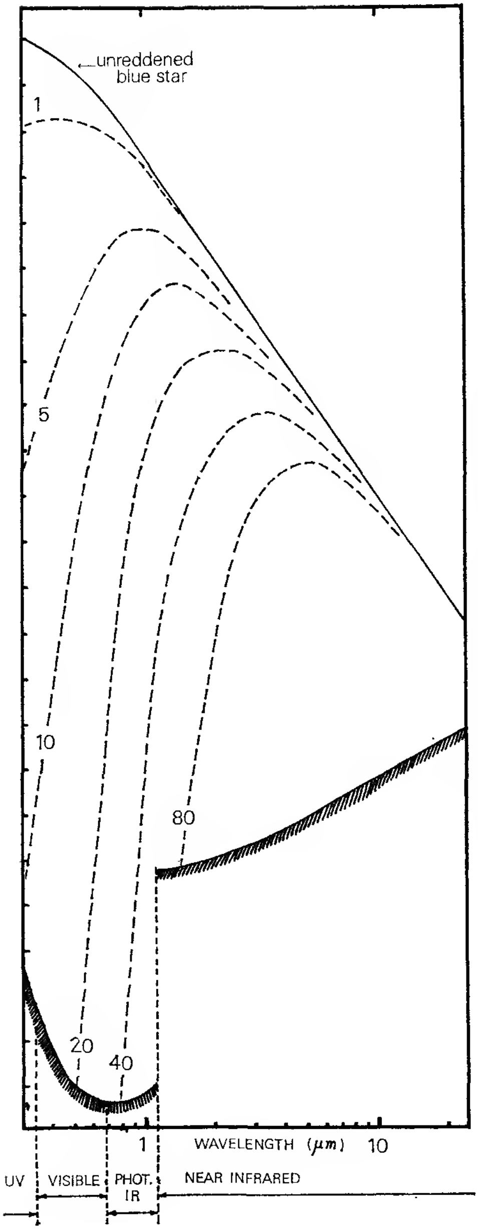


Fig. 2. The energy distributions of reddened stars in the visible and infrared. A hot star peaks in the ultra-violet (top curve) and the effect of interstellar extinction is to make it fainter and redder. The figures accompanying the curves are visual extinction, A_v, in magnitudes, and the ordinate is also in magnitudes. The hatched line at the bottom of the diagram shows the faintest star we could detect with the world's largest telescopes if the unreddened star were as bright as zero apparent magnitude. A star with an $A_v \geqslant 40$ can never be detected at visible wavelengths.

an A_V of 80 magnitudes or so; this is illustrated in Figure 2. So as not to endanger the reputation of this hallowed periodical, I should perhaps caution that this interpretation, and its application to the other objects I shall discuss below, is no more than a convenient hypothesis, one possible way of interpreting the available data; though some very recent observational evidence seems to corroborate it, the possibility exists that this theory will be proved incorrect in the near future, and, maybe, even before this Yearbook appears in print.

The exciting result of this conjecture is not that we may have discovered a star reddened eight times as much as any previously known; rather that the underlying star must be one of the most luminous in our Galaxy. Indeed, the only individual object known which exceeds Becklin's star in its total energy output is the incredible Eta Carinæ. Stars of the required luminosity are known in other galaxies (for example S Doradûs in the Large Magellanic Cloud), and generally result from very massive stars undergoing the first stages of evolution off the main sequence. On our interpretation, Becklin's star is the biggest and brightest object in the nebula, the central *lucida* of a compact cluster of young stars in a cloud so murky that we can see only the outer rind on the face nearest to us. Indeed it is only because a group of stars (the Trapezium) lies just on the outside edge of the cloud that we see it illuminated at all; viewed from the other side M42 may be quite black. And just what lurks deep in the interior is anybody's guess.

Professor Reddish (of the Royal Observatory, Edinburgh) some years ago noted a relationship between reddening and luminosity. Specifically he found that the brightest stars in our Galaxy tend to have the greatest reddening. Becklin's star clearly fits on to such a trend, though I am sure Reddish had no idea that such an object might exist when he published his findings. It occurred to me that if Reddish's relationship were a reliable generalization, and if our interpretation of Becklin's star were correct, there would be a good chance of finding similar objects by looking in the right places. In 1971 I began to search various likely nebulæ for infrared sources too faint to have been recorded by Neugebauer and Leighton's 2 μm survey. Of the many I found, most were normal stars, but two were relevant to this discussion.

One lies in Taurus, and is probably the star which illuminates IC 2087, a faint nebulous patch in an otherwise blank region of the sky. A_V for this star is 30 magnitudes if the heavy reddening interpretation is correct; however, this particular infrared source is perhaps better explained by a more conventional picture, and I will not therefore dwell further on it. The other source is in NGC 2264, the cluster of young stars around S Monocerotis, a cluster which is so splendid a sight in a small telescope. Many observers do not realize that the cluster extends half a degree south of the principal star, and it is the southern section which is shown in Figure 1. The brightest stars on this photograph are from 8th to 10th magnitude. The infrared source, marked by an arrow, lies at the very apex of a triangular nebulous fan which shows up brightly in this red photograph. I should caution enthusiastic readers who may be dashing out to set up their telescopes and look at this tiny nebula that I have been unable to see it in any smaller an instrument than the Mount Wilson 100-inch. The nebula itself is very red and shows up much better at near-infrared wavelengths, but if we observe at still longer wavelengths, it is the point source at its apex which dominates the area.

At about the same time that I found the NGC 2264 infrared source, a team led by Professor Zuckerman of the University of Maryland discovered that an area around the nebulous fan is a source of molecular line emission in the microwave region of the spectrum. This discovery came quite by chance – the intention of Zuckerman's team was to observe a different part of NGC 2264, but they used the wrong co-ordinates and pointed their radio telescopes directly at the infrared source instead! Once again the molecular observations tell us that a very dense cloud lurks in the vicinity, the total visual extinction across this one being about 70 magnitudes. Whereas the Orion nebula is made visible by the Trapezium stars, the NGC 2264 (Monoceros) nebula is invisible but for that one tiny fan.

The infrared source in the Monoceros Nebula is roughly as luminous as Becklin's star and has an A_V of about 50 magnitudes. If the obscuring dust were suddenly to be removed, the star would be of zero apparent magnitude – a thousand times brighter than the brightest stars of Figure 1 and a striking addition to the 'Winter Triangle'. Apparently the Monoceros Nebula is patchy, for while 50 magnitudes of extinction lie in our direction, A_V is less than 10 magnitudes in the direction roughly north-west of the star, so that a beam of its radiation, like a searchlight, spreads out to form the nebulous fan we see on photographs. It also looks as though radiation is leaking through to the south. The outline of the Cone Nebula at the bottom of Figure 1 comprises a series of straight line sections interrupted by denser, resistant, bubbles of material. If these individual lines are projected northwards, they all meet at the position of the infrared source. By a cruel trick of Nature the curtain is down and we seem to be in about the least privileged of positions for seeing this, one of the brightest and most interesting stars in our Galaxy.

We began by seeking the most heavily reddened stars we could find. We now realize that there must be thousands – even millions – for which the extinction has values of tens or even hundreds of magnitudes. The great majority of these we will never be able to detect, and so the problem now becomes that of finding the most luminous stars in the Galaxy, stars which are bright enough to be recorded by the rather insensitive detectors we used at infrared wavelengths. We do not know how many such stars we may ultimately find, and survey work at infrared wavelengths is a painfully slow process. Maybe by the time this article appears in print, we will have doubled or trebled the size of the collection. Maybe not. It really depends on how well we guess where to look. In a field such as this we are really groping around in the dark nebulæ.

Recent Advances in Radio Astronomy

NICHOLAS TATE

Although radio astronomy is still a very new science, its rate of progress has been incredibly rapid, and over the last few years we have seen great advances in our knowledge of the universe, which have come about mainly due to the ability to see cosmic events at wavelengths that are normally invisible to the human eye.

Such advances as the discovery of quasars and later of pulsars have provided a great deal of information for the theorists and served to show the tremendous value of radio astronomy as a technique. This article is an attempt to review some of the more recent progress in this vast field.

One great difficulty with radio astronomy is that due to the wavelengths of the radiation involved, one has to build very large radio telescopes in order to give them a resolution or 'separating' power of the same order as that of a good optical telescope. For instance even the 250-ft Mk. 1 radio telescope at Jodrell Bank, which is one of the biggest of its type in the world, cannot provide the same sort of resolution as a medium-power optical telescope.

This difficulty, of course, puts radio astronomers at a great disadvantage compared with their optical counterparts, since they cannot separate out bright sources which are close together. This poses quite a few problems, because if a radio astronomer discovers a bright source, but is uncertain about its position, he cannot link it up with any known optical object, as there may be many within the error field of the source. This means that he cannot make an accurate radio map of the sky.

There are, however, two main ways of surmounting this problem. First is the obvious one of building bigger instruments, but unfortunately this requires a great deal of engineering skill and an even greater amount of money. The second method has been in use at Cambridge since 1957 and is known as 'aperture synthesis', in which two or more small aerials are moved to occupy in turn the positions of the elements of a much larger aerial. The information gained from the small aerials, in these different positions, is then fed into a computer which combines them to make a map of the sky as seen by a larger radio telescope. In other words, if the radio telescope aerial consists of a lot of small aerials which can be moved along a one-mile piece of railway track, then by putting these aerials in various positions and feeding the results to a computer, a map of the sky may be made. This map will be one as seen by a one-mile diameter dish aerial. This method gives a very great increase in resolution, for a much smaller cost than building bigger and bigger aerials.

On 17 October, 1972 the President of the Royal Society, Sir Alan Hodgkin, inaugurated the new 5 km aperture synthesis radio telescope at the Mullard Radio astronomy observatory of the Cavendish laboratory at Cambridge. This new radio telescope is particularly important; because it is so big compared with previous telescopes of half-mile and one-mile, it has a very much greater resolution – a resolution, in fact, comparable with that of the best optical telescopes. The instrument itself consists of eight dishes, each 13 metres in diameter, on an east-west axis of 4·6 km and will provide angular resolutions of the order of 1 to 7·5 arc s. at wavelengths of 3-21 cm.

Looking to the future, then, it can be hoped that this new advance in instrumentation will enable radio astronomers to make much more accurate maps of the sky. These may then settle some of the problems concerning the positions of optical and radio sources which are at present unsolvable. However, 1972 has provided us not only with a big advance in instrumentation but also with an unusual new radio source. On the evening of Saturday, 2 September, 1972, researchers at the University of Toronto recorded possibly the most impressive outburst ever witnessed by radio astronomers. The outburst was from the X-ray source Cygnus X-3, and was first observed at a frequency of 10·5 GHz. It was found that the radio emission had increased a thousandfold above the level recorded previously at the U.S. National Radio Astronomy Observatory.

Cygnus X-3 had been observed before as a weak but variable source in the radio region, but was also known to be an X-ray source. Radio astronomers, thinking that there might be a parallel outburst at X-ray frequencies, turned satellite-based X-ray telescopes on to it. No corresponding increase in X-ray emission was, however, observed. This caused some puzzlement, as it had previously been thought possible that the outburst might be due to thermal causes, but the lack of an outburst at X-ray frequencies served to disprove this theory.

The picture that has now emerged after combining observations at a number of different frequencies, is that of a cloud of very high-velocity particles, moving at a velocity close to that of light and expanding within a magnetic field. Such a system would produce what is known as Synchrotron radiation, a type of radiation fairly common to non-thermal sources. Pulsars and supernovæ are, however, the only known sources of the very high velocity particles which have been observed. It would appear, then, that this could be a completely new type of radio source, which has been overlooked in previous surveys of the sky.

So far, astronomers have been unable to detect Cygnus X-3 optically; but various estimates of distances have been made. French radio astronomers have obtained an estimate of between 8 and 11 kiloparsecs, but this is, at the moment (Jan. 1973), a little uncertain; nevertheless, all are agreed that the source is in our Galaxy.

It seems unlikely that Cygnus X-3 is unique in its outburst, and it may well be that in the future radio astronomers will be able to discover more objects like it, now that they know what to look for. This could well foretell a new class of objects in astronomy.

The period under review has been fairly devoid of any more startling revelations concerning pulsars. It is now generally held that pulsars are neutron stars, that is to say incredibly dense stars that are in one of the final stages of evolution. Since the discovery of the first pulsar, at Cambridge, a large number have now been found and some have been identified optically.

Pulsars are also thought to have some connection with supernovæ and the Crab Nebula (known to have at least one pulsar within it) is being studied in order to try and provide some clue as to the connection between them. Meanwhile, much basic research is continuing into the whole topic of pulsars, and no doubt more information about them will soon be obtained from this work.

Those hardy perennials, quasars, are still defying explanation, and the debate continues as to whether they are very high power sources, a long way off, or moderate power sources which are fairly near (that is, within the Galaxy). Some astronomers hold the former view, whilst others hold the latter, and a third group cannot make up its mind. Altogether a number of scientists are questioning the validity of the 'long way off' explanation, that is to say the red shift law for determining distance, and so there has been no really fundamental advance in our knowledge of quasars.

Over the last few years a great deal of work has been done in searching for complex molecules in interstellar space by radio means. These molecules are discovered by using radio telescopes, to produce a spectrographic map at radio frequencies, and by then using spectral lines to identify the molecules in the same way as in optical spectroscopy. This technique has led to the discovery that some of the very complex molecules, necessary to life as we know it, exist in interstellar space.* The importance of this is that it shows us that complex molecules are not just built up in planetary conditions, but may be part of the 'dust' from which a planet is formed.

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* See the article by Dr. Simon Mitton in this *Yearbook.*

This sort of work often goes somewhat unreported, because it is not quite as spectacular as the discovery of a pulsar or a quasar, but it is nevertheless very important and big advances are being made in this field.

With the ending of the Apollo programme, the chances of having a manned base on the Moon for astronomical research in the near future seem very small, a great pity since a radio telescope on the Moon would, due to the lack of hindrance of an atmosphere, be able to provide far more information than an earth-based counterpart. We can still hope, though, that during the Skylab and space shuttle eras, important work will be done from Earth's orbit, as is done at present by satellites.

It may seem from this description of recent events that all work in radio astronomy must be done by professionals, because it is either too difficult or too expensive to be done by amateurs. This is not by any means true; useful work has been, and is being, done by amateurs – and there exists a special section of the British Astronomical Association devoted to radio astronomy.

Whilst it is true that opportunities for amateur work are limited, for obvious reasons of expense, it is nevertheless possible for amateurs to make contributions, in fields where a lot of observations, over a long time are needed, such as in the study of the 'radio sun'. The amount of specialist radio knowledge required is about that of most radio amateurs, and the expense is often no more than that of a moderate optical telescope.*

In conclusion, then, it has been a fairly eventful period in radio astronomy, and we can look forward to the coming year in the hope that more light will be shed on some of the currently baffling problems such as that of quasars.

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* For more information on amateur radio astronomy, readers are advised to contact the radio astronomy section of the British Astronomical Association, the address of which can be found in the back of this book.

Recent Advances in Astronomy and Astronautics

PATRICK MOORE

The year 1973 has been memorable in several respects. In particular, it has seen the first major "repair work" in space. So much faith had been placed in the American Skylab vehicle that there was consternation when it ran into trouble, immediately after having been launched. One of the solar panels was torn off, and the other did not extend properly; there was serious overheating inside the space-ship itself, and for a time it was even thought likely that the crew (Astronauts Conrad, Kirwin and Weitz) would be "grounded". Fortunately this did not happen, and after a troublesome period in docking the astronauts were able to carry out extensive repairs —not without considerable danger to themselves, because several space-walks were involved.

At the time when these words are being written (15 June 1973) the crew of Skylab are still in orbit. We have every reason to hope that their mission will be completed successfully, and that they will be followed by the second crew, commanded by Astronaut Alan Bean — who, like Charles Conrad, has been to the Moon. (Conrad and Bean went with Apollo 12 in November 1969.) Plans to undertake a joint American-Russian venture in 1975 are also going ahead. On 15 July 1975 a Soviet Soyuz will be launched, to be followed a few hours later by an Apollo-type American space-ship, and the two will link up.

However, much work remains to be done, and there is no doubt that Russia's Soyuz 2, of 1973, was a failure. No cosmonauts went up to it, and it seems that nothing of real value came from it.

Meantime, an automatic vehicle has been put into a path round the Moon, for purely astronomical purposes; this is the last American Moon-shot of the 1970s. There are also the two Pioneers to Jupiter, the first of which (Pioneer 10) is scheduled to make its fly-by of the Giant Planet in the early part of December 1973; Pioneer 11 will follow about a year later. Neither will land, and neither will remain in the Solar System. Once their work is done, they will fly on into space between the stars.

In the field of what may be called "pure" astronomy, the main event of 1973 was the total eclipse of the Sun. Over parts of Africa, totality lasted for more than seven minutes, which is practically a record. But there was also Kohoutek's Comet, which showed signs of being the brightest for over a century.

It was discovered when still a long way from the Sun, and extremely faint; but calculations showed that around December 29 it would possibly become bright enough to be visible with the naked eye in broad daylight. Comets of this kind were not too rare during the nineteenth century (1811, 1843, 1858, 1861, 1882 in particular) but have been very uncommon since; the last was the Daylight Comet of 1910, though it is true that the Arend-Roland Comet of 1957 and Bennett's of 1970 both became bright enough to attract general interest.

Again, let me repeat that I am writing in June 1973; Comet Kohoutek is approaching steadily, but as yet we simply do not know how brilliant it will become. At the worst, it should be comparable with Venus; at the best, with the half-moon. It may be expected to have a long tail, though we cannot yet tell what form this tail will take.

Like all really brilliant comets, Kohoutek has a period so long that it will not return to the Sun for many thousands of years. (The only fairly bright comet with a period of less than a century is Halley's, which will be back once more in 1986.) It is not impossible that our new visitor is the first of several — in which case, great comets may be much more frequent during the last quarter of our century than they have been up to now; but it is always dangerous to make forecasts about comets.

So far as stellar astronomy is concerned, there has been continued discussion about the so-called "black holes", and X-ray astronomy has been very much to the fore. The trouble here, of course, is that short-wavelength radiations are blocked by layers in the Earth's upper atmosphere, and this means that equipment has to be sent up in rockets or satellites; when we succeed in establishing a really efficient space-station, the benefits to astronomy will be immense. (Skylab is the first step in this direction.)

Much attention was paid to an X-ray source in the constellation of the Swan, known as Cygnus X-1. This has been known for some time as a powerful emitter, and it seemed, from movements of the source, that the X-rays were coming from a star over ten times as massive as the Sun. This presents some problems, and there were suggestions that the real cause might be a collapsar – that is to say an extremely small, super-dense body surrounded by a black hole. The X-radiation could then be due to material falling in toward the collapsar at high velocities, building up energy which could be converted into heat – and, hence, producing X-rays. This intriguing theory has however been challenged, and it is also thought possible that there is no collapsar and no black hole; instead there are two stars which have immensely strong magnetic fields, which become entwined as the stars spin around. The magnetic lines of force are periodically broken and then reconnected, with the release of energy and the production of X-radiation.

Collapsars and black holes may well exist, but for obvious reasons they cannot be directly observed. Quasars and pulsars, both discovered during the 1960s, definitely exist, and have been the subjects of intense investigation over the past year, Despite the similarity of name, there is no connection between the two. A quasar is undoubtedly extragalactic; according to the current evidence a typical quasar is much smaller but much more powerful than a galaxy, and distances range out to several thousands of millions of light years. If we interpret the spectral red shifts as Doppler effects, it seems that one quasar, studied in 1973, is racing away from us at well over 90 per cent. of the velocity of light. Not all authorities accept this interpretation; but in any case, quasars are very remote indeed.

Pulsars, on the other hand, are members of our Galaxy, and there is no longer any serious doubt that they are neutron stars. The only one optically identified lies in the midst of that remarkable object the Crab Nebula, and has been described as "the Crab's Power-house"; no doubt many others could be seen were they closer to us. (It is true that in many ways the Crab, which lies at a distance of 6,000 light-years, is exceptional.) The former theory that a pulsar might be a rapidly-vibrating White Dwarf has been rejected.

White Dwarfs are not so extreme in density as pulsars, but they are remarkable things; the best-known is the Companion of Sirius, which has only three times the diameter of the Earth, but is almost as massive as the Sun. Other White Dwarfs are considerably smaller, and even denser. An interesting discovery was made in 1973 by W. J. Luyten and P. Higgins, at the University of Minnesota, when they were processing a pair of Palomar Sky Survey plates. At R. A. 9h42m19s, declination +23°41′.4, they found a double white-dwarf system, now known as LP370-50/51. The pair has a magnitude of 16; assuming a parallax of 0″·02 the linear separation is of the order of 600 astronomical units, and the period of revolution is about 12,000 years.

With instrumental astronomy, possibly the main event of the year has been the setting-up of the new observatory at Sutherland, in South Africa, where most of the main instruments in the South African Republic have been taken; the Director is Sir Richard Woolley, formerly Astronomer Royal. Meantime, it is assumed that testing for the 236-inch Russian reflector is continuing in Siberia, though remarkably little positive information has yet been released.

When Sir Richard Woolley retired as Astronomer Royal, it was generally assumed that the new Director at Herstmonceux would also become Astronomer Royal. This did not prove to be the case. Dr Margaret Burbidge went to Herstmonceux; Professor Sir Martin Ryle, the great radio astronomer, became Astronomer Royal. So there is a break with tradition; but nobody will dispute that Sir Martin has well deserved the honour. There are few people who have done as much for astronomical science.

PART THREE

For Stellar Observers

Unpredictable Stars

PATRICK MOORE

In ancient times the sky was thought to be changeless. Apart from the wanderings of the Sun, Moon, and planets, and the ceaseless turning of the heavens in making a full turn in 24 hours, it was believed that nothing could ever happen. Occasionally a comet would appear, becoming brilliant for a while; sometimes there occurred an eclipse – though eclipses, at least, could be predicted with fair accuracy.

What really upset the 'changeless sky' idea was the appearance of novæ, or temporary stars. One, which blazed out in 1054, has left the gas-cloud we know as the Crab Nebula, though when at its brightest it attracted curiously little attention except in China. Then, in 1572, came Tycho's Star in Cassiopeia, which – like the Crab star – was a supernova, and became bright enough to be visible with the naked eye in broad daylight. Certainly the sky could no longer be regarded as devoid of change.

In modern times we know not only of novæ, but also of the many variable stars. These have been described in past *Yearbooks*, and are of many kinds. Some – the Cepheids, for instance – are absolutely regular. Others, such as Mira Ceti, have well-marked periods, but are subject to fluctuations in both period and range. And there are yet others which seem to be entirely irregular in behaviour. The present article is concerned with these unpredictable stars. You may watch them for years – perhaps throughout your lifetime – without noting anything of real interest; but there is always the chance that one of them will 'do the unexpected', and in this case it is the amateur who has

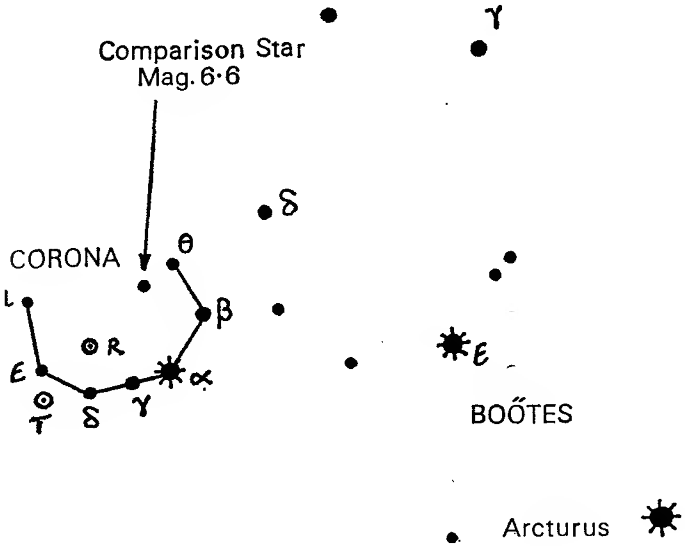


Fig. 1. **Positions of R and T Coronæ.**

probably the best chance of catching it in the early stages of its performance.

Two of these erratic stars lie in the small but well-marked constellation of Corona Borealis, the Northern Crown. One, T Coronæ, is known commonly as the Blaze Star. It is easy to locate from the guide-star, Epsilon Coronæ, and a small telescope will show it, since its normal magnitude is almost 10. But twice during the past century and a half it has caused a sensation.

In 1855 Argelander, a famous German astronomer who drew up an excellent star catalogue, had recorded T Coronæ as of the 10th magnitude. Then, on 12 May, 1866, the Irish astronomer Birmingham found that it was of the second magnitude – as bright as Alpha Coronæ! Combining this observation with another made by Schmidt from Athens, it seems that the star brightened up from magnitude 4 to 2, on 12 May, in only three

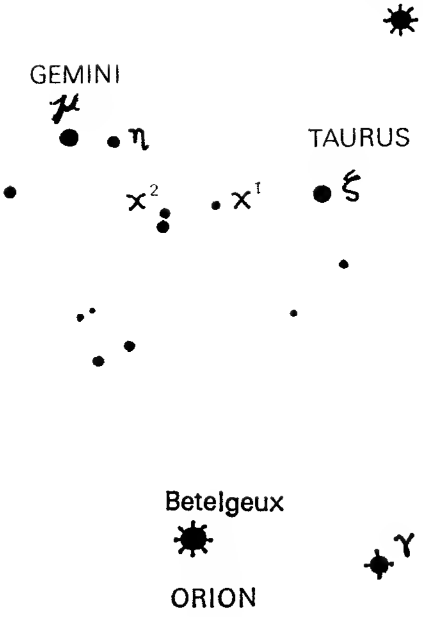


Fig. 2A. **Positions of χ^1 and χ^2 Orionis. (Naked-eye view.)**

hours. It soon faded, and dropped to magnitude 9; in September it increased once more to magnitude 7, but then returned to its old brightness. Nothing much happened thereafter until February 1946, when there was another sharp rise, this time to the third magnitude, followed by a sharp fall. Subsequently T Coronæ has remained at minimum, with only slight variations.

It has been found that the star is a binary, made up of a B-type primary which is the cause of the occasional outbursts, together with a red giant which is itself irregularly variable over a small range. The slight fluctuations near minimum are due to the red star; the B-type white star is a typical recurrent nova.

At the moment T Coronæ is 'quiet'. It has been so ever since I began observing it, a decade ago. It may remain at the 10th magnitude for another eighty years – or even longer. All the same, one never knows; if a rise occurs, it will be quick; and for this reason I make an observation of it every night. Of course, if it does flare up, it will be very evident to the naked eye. I hope it will happen while I am still around to watch it!

T Coronæ is not the only recurrent nova. Others are RS Ophiuchi (range 11·7 to 5; outbursts in 1901, 1933, 1958, and 1967), and the southern T Pyxidis (14 to 7; 1890, 1902, 1920, 1945, and 1965). A rather different kind of star, WZ Sagittæ, burst forth in 1913 and again in 1946. Serious stellar observers could well pay attention to these strange objects.

Returning to Corona, we find here the famous variable R, which is normally on the fringe of naked-eye visibility. Here we have the prototype of a class of remarkable variables. At irregular intervals R Coronæ drops sharply to minimum, and may plunge down to below the 14th magnitude. It last did so in the first part of 1972. The decline began in late February, and the star fell to magnitude 12½ by mid-April, after which there was a slow and relatively steady climb back to maximum by the beginning of August. Since then, up to the time I write these words (March 1973) the magnitude has been constant to a tenth or so either side of 6·0; but one never knows when a new drop will occur.

From the amateur's point of view, the beauty of R Coronæ is that normally it is visible with binoculars, inside the bowl of the Crown, and there is a convenient star of magnitude 6·6, also in the bowl, to act as a comparison. Therefore, the binocular-user should always make a quick inspection; and if R is as faint or fainter than the comparison, then it is likely that a decline to minimum has begun.

R Coronæ and its kind are known as carbon stars, because their atmospheres are carbon-rich and hydrogen-poor. It may well be that carbon particles in the outer atmospheres are responsible for the minima – acting as a kind of screen. Members of the class are not numerous, but there is one more which is north of the equator and is normally easy. This is SU Tauri, where the normal magnitude is between 9 and 10 and the deepest minimum probably around 16. It is not hard to locate, near the boundary between Taurus and Orion; indeed, the guide-stars that I personally use in finding it are those in the field of the famous long-period variable U Orionis. SU Tauri went through a minimum in 1971, had recovered to near-maximum by mid-1972, and again started to fall in February 1973, so that at present (March 1973) it is beyond the range of the 12½-inch reflector in my observatory. No doubt it will reappear in this telescope well before the publication of this *Yearbook*. Of course, SU Tauri is a star near the Zodiac, so that for some time in the summer it is too near the Sun to be observed; unlike R Coronæ, it cannot be followed almost throughout the year.

Other R Coronæ stars are S Apodis, UW Centauri, DY Centauri, Y Muscæ, RT Normæ, RY Sagittarii, and RS Telescopii. All these are in the far south, and only RY Sagittarii (range mag. 6 to 14) ever rises over Europe. It seems that these southern R Coronæ stars have not been followed as extensively as would be wished – and there is a great opportunity here for southern amateurs to undertake really useful work.

Quite different are the flare stars, nearby Red Dwarfs which may brighten up by magnitudes over a period of minutes, fading back to normal brightness quickly. The prototype is UV Ceti, which is actually the fifth nearest star to the Sun. In 1947 Carpenter found that it had increased by two magnitudes in only 20 minutes. Then, in September 1952, it was found to rise from its normal magnitude (12·9) to 5·9 in a short period – and maximum lasted for only five minutes before the fade began!

A very convenient flare star is AD Leonis, which lies in the field of the second-magnitude Gamma Leonis. Here the range is smaller (magnitude 9·5 to 9, so far as we know) but the flares seem to be fairly frequent. Because of their faintness, most other stars of the kind are less easy to locate, but we do have DO Cephei (usual magnitude 11·4), YZ Canis Minoris (11·6), and EQ Pegasi (11·3), among others.

Observing flare stars needs a different technique from that usually employed by variable star observers. During a 'patrol',

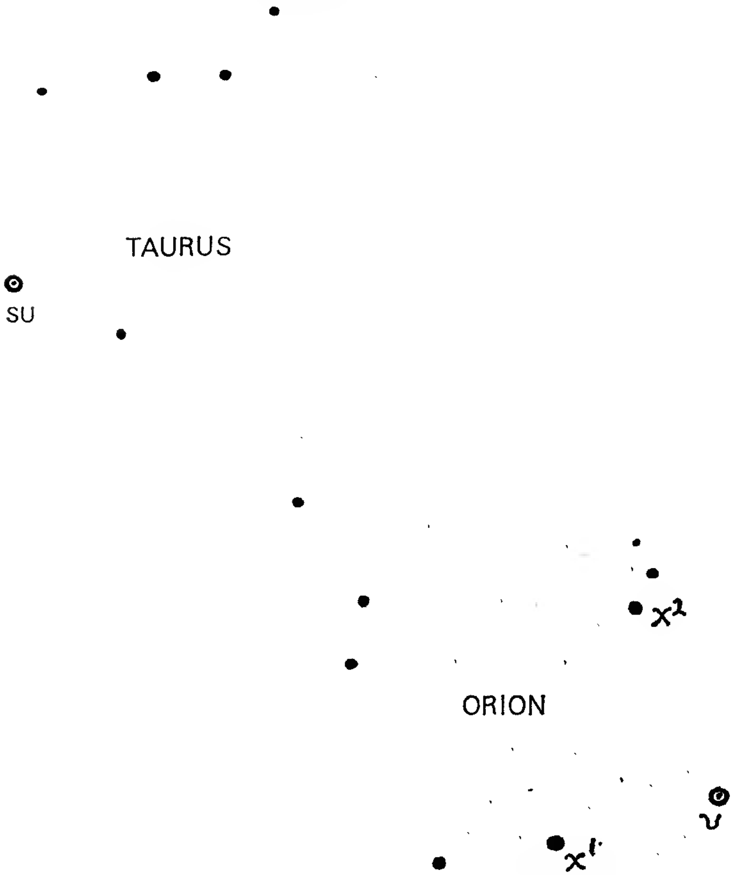


Fig. 2B. Telescopic view: 3 degree field – SU Tauri.

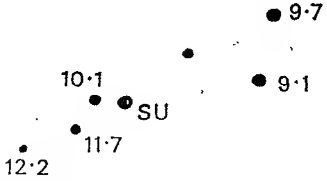


Fig. 2C. High-power field of SU Tauri (figures indicate magnitudes).

to be carried out visually, one really needs several observers, manning the same telescope for periods of ten minutes each – it is difficult to concentrate continuously for longer than that. In 1973 I took part in one such patrol, of AD Leonis, using my 12½in. reflector. We recorded three flares in a period of seven hours.

The recurrent novæ, the R Coronæ variables and the flare stars are all completely unpredictable in their various ways. To a lesser extent, so are the long-period variables of which Mira Ceti is the prototype. The period of Mira is 331 days on average, but the interval between successive maxima is not constant; neither is the brightest magnitude. In 1868 it apparently failed to reach even the fourth magnitude, but in 1969 I recorded it as only just below the second. At minimum the magnitude is below 9, so that a telescope is needed rather than binoculars. Other Mira-type stars behave in similar ways; they are excellent subjects for amateur observation, but at least their eccentricities are confined within bounds!

Then we have the so-called dwarf novæ, of which the brightest example is SS Cygni. These too are unpredictable, because one never quite knows when they will brighten up, or how long a maximum will last. SS Cygni itself ranges between magnitude 8¼ and 12¼, and the mean interval between outbursts is around seven weeks. Toward the end of 1972 and early in 1973 the fluctuations were even less predictable than usual, and so it is definitely a star to be watched. Fortunately it is easy to locate, not far from the naked-eye Rho Cygni – the guide star, Flamsteed 75 Cygni, is distinctly red. SS itself lies within a well-marked triangle of telescopic stars.

To describe other variables of these types would take many pages, and would be beyond the scope of the present article; all I aim to do is to stress that they are objects which should be kept under constant watch – something which no professional astronomer is likely to have the time or the inclination to do. And, of course, there is always the chance of discovering a nova, as many amateurs have done. Nova DQ Herculis

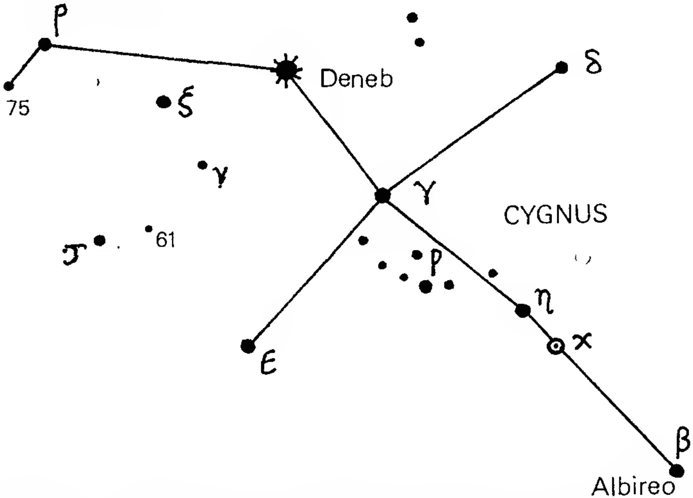
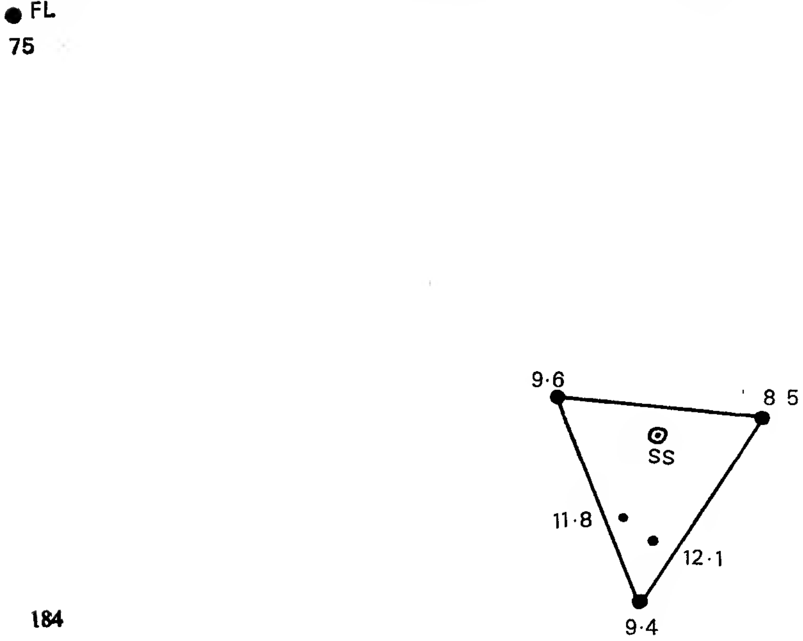


Fig. 3. ABOVE: P Cygni and position of Fl. 75 Cygni. (Naked-eye view.) BELOW: Telescopic field of SS Cygni (figures indicate magnitudes).



was found in 1934 by J. P. M. Prentice, then Director of the Meteor Section of the British Astronomical Association, who was taking a nocturnal stroll following a period of meteor observation. More recently G. E. D. Alcock, from Peterborough, has found no less than three novæ; the famous HR Delphini, LV Vulpeculæ, and the nova in Scutum – though let us add that he was undertaking a systematic nova-hunt, so that the discoveries cannot be attributed to sheer luck.

Finally, let us note three stars which are utterly wild in their behaviour. P Cygni, near Gamma Cygni in the centre of the 'Northern Cross', has been described elsewhere; it has remained at about the fifth magnitude for over 300 years, but it is so unstable that it may start to fluctuate again at any time. Gamma Cassiopeiæ, the middle star of the 'W', has remained just below the second magnitude for several decades; but in 1936 it brightened up to 1·6, subsequently dropping to just below magnitude 3 in 1939 before making a recovery. It, too, is unstable, and it is worth watching, because a new increase may be not long delayed. Beta Cassiopeiæ and Polaris are suitable comparison stars. (Alpha Cassiopeiæ, or Shedir, is also of around the same brilliancy, but has been strongly suspected of variability over a small range.)

In the far south, unfortunately inaccessible to Europeans and most North Americans, lies the remarkable object known originally as Eta Argûs and latterly, following the undignified chopping-up of the Ship Argo, as Eta Carinæ. In 1677 Halley rated it as of magnitude 4; in 1751, Lacaille graded it magnitude 2; and between 1811 and 1815 Burchell again made it magnitude 4. By 1822 it had once more increased to the second magnitude (Fallows, Brisbane); by 1827 it had reached equality with Acrux, the first-magnitude leader of the Southern Cross (Burchell was the observer here). By 1828 it was again of magnitude 2 (Johnson, Taylor); but in 1834 Sir John Herschel, who was then making his classic sky-survey from the Cape of Good Hope, ranked it above 2, though below 1. Then, on 16 December, 1837, Herschel was startled to find that it had

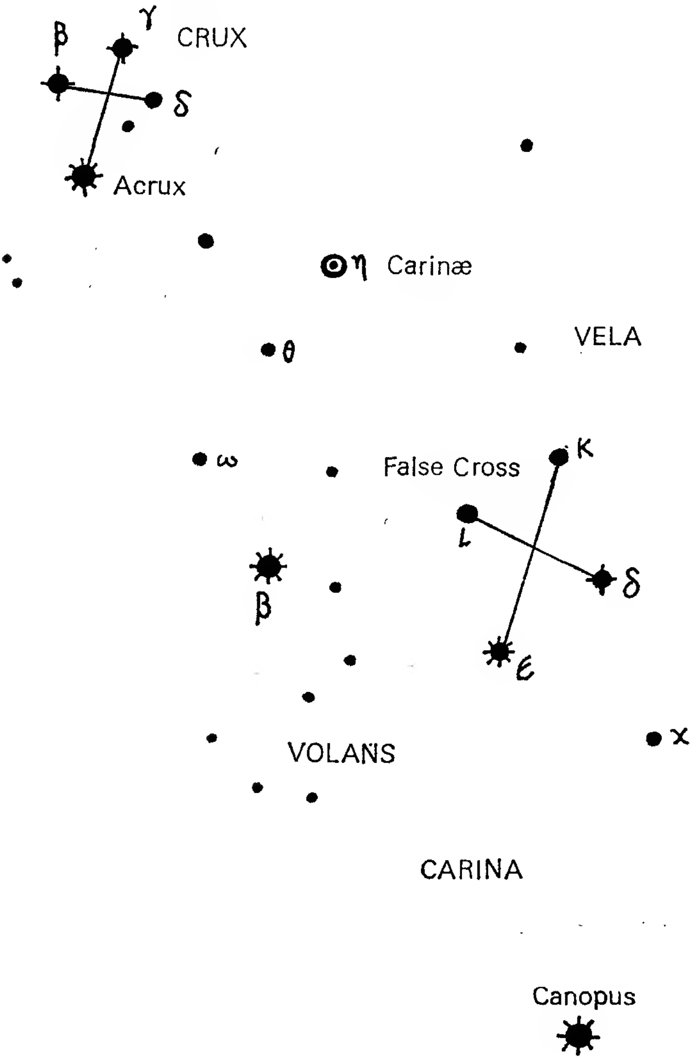


Fig. 4. **Position of η Carinæ.**

become brighter than any star in the sky apart from Sirius and Canopus. This continued well into 1838. Following a decline, there was a fresh increase in 1843, and Mackay, at Calcutta, and Maclear, at the Cape, made Eta Carinæ even brighter than Canopus, so that Sirius alone surpassed it.

This was not maintained, and subsequently the magnitude fell steadily. The estimates given were 0 in 1850 (Gilliss), 2½ in 1858 (Powell), 3 in 1860 (Tebbutt), 4½ in 1861 (Abbott), 5 in 1863 (Ellery), 6 in 1867 (Tebbutt). Since then it has never been visible to the naked eye, though its magnitude has not dropped below 7½ (Finlay, in 1886).

Eta Carinæ is involved in nebulosity, and is in every way an exceptional object. This is not the place to enter into theoretical speculations; but at any rate, one fact is clear – a hundred and thirty years ago it was one of the very brightest stars in the sky, and in the future it may be so again. Southern observers would be well advised to keep a watch on it.

These, then, are some of the stellar curiosities. There are many others; not all stars are predictable, and some are so erratic that one can never tell what they are liable to do next.

Some Interesting Telescopic Variable Stars

Star	R.A.		Dec.		*Mag. range*	*Period, days*	*Remarks*
	h	*m*	°	′			
R Andromedæ	0	22	+38	18	6·1–14·9	409	
W Andromedæ	2	14	+44	4	6·7–14·5	397	
R Aquilæ	19	4	+ 8	9	5·7–12·0	300	
R Arietis	2	13	+24	50	7·5–13·7	189	
R Aurigæ	5	13	+53	32	6·7–13·7	459	
R Boötis	14	35	+26	57	6·7–12·8	223	
R Cassiopeiæ	23	56	+51	6	5·5–13·0	431	
T Cassiopeiæ	0	20	+55	31	7·3–12·4	445	
T Cephei	21	9	+68	17	5·4–11·0	390	
Omicron Ceti	2	17	− 3	12	2·0–10·1	331	Mira.
R Coronæ Borealis	15	46	+28	18	5·8–14·8	–	Irregular.
W Coronæ Borealis	16	36	+37	55	7·8–14·3	238	
R Cygni	19	35	+50	5	6·5–14·2	426	
U Cygni	20	18	+47	44	6·7–11·4	465	
W Cygni	21	34	+45	9	5·0– 7·6	131	
SS Cygni	21	41	+43	21	8·2–12·1	–	Irregular.
Chi Cygni	19	49	+32	47	3·3–14·2	407	Near Eta.
R Draconis	16	32	+66	52	6·9–13·0	246	
R Geminorum	7	4	+22	47	6·0–14·0	370	
U Geminorum	7	52	+22	8	8·8–14·4	–	Irregular.
S Herculis	16	50	+15	2	7·0–13·8	307	
U Herculis	16	23	+19	0	7·0–13·4	406	
R Hydræ	13	27	−23	1	4·0–10·0	386	
R Leonis	9	45	+11	40	5·4–10·5	313	Near 18, 19.
X Leonis	9	48	+12	7	12·0–15·1	–	Irregular (U Gem type).
R Leporis	4	57	−14	53	5·9–10·5	432	'Crimson star.'
R Lyncis	6	57	+55	24	7·2–14·0	379	
W Lyræ	18	13	+36	39	7·9–13·0	196	
HR Delphini	20	40	+18	58	3·6– ?	–	Nova, 1967.
LV Vulpeculæ	19	45	+27	2	4·8– ?	–	Nova, 1968.
U Orionis	5	53	+20	10	5·3–12·6	372	
R Pegasi	23	4	+10	16	7·1–13·8	378	
S Persei	2	19	+58	22	7·9–11·1	810	Semi-regular.
R Scuti	18	45	− 5	46	5·0– 8·4	144	
R Serpentis	15	48	+15	17	5·7–14·4	357	
SU Tauri	5	46	+19	3	9·2–16·0	–	Irregular (R CrB type).
R Ursæ Majoris	10	41	+69	2	6·7–13·4	302	
S Ursæ Majoris	12	42	+61	22	7·4–12·3	226	
T Ursæ Majoris	12	34	+59	46	6·6–13·4	257	
S Virginis	13	30	− 6	56	6·3–13·2	380	
R Vulpeculæ	21	2	+23	38	8·1–12·6	137	

Some Interesting Double Stars

The pairs listed below are well-known objects, and all the primaries are easily visible with the naked eye, so that right ascensions and declinations are not given. Most can be seen with a 3-inch refractor, and all with a 4-inch under good conditions, while quite a number can be separated with smaller telescopes, and a few (such as Alpha Capricorni) with the naked eye. Yet other pairs, such as Mizar-Alcor in Ursa Major and Theta Tauri in the Hyades, are regarded as too wide to to be regarded as bona-fide doubles!

Name	*Magnitudes*	*Separation,"*	*Position angle, deg.*	*Remarks*
Gamma Andromedæ	3·0, 5·0		060	Yellow, blue. B is again double (0"·4) but needs a larger telescope.
Zeta Aquarii	4·4, 4·6	2·6	291	Becoming more difficult.
Gamma Arietis	4·2, 4·4	8	000	Very easy.
Theta Aurigæ	2·7, 7·2	3	330	Stiff test for 3 in. OG.
Delta Boötis	3·2, 7·4	105	079	Fixed.
Epsilon Boötis	3·0, 6·3	2·8	340	Yellow, blue. Fine pair.
Kappa Boötis	5·1, 7·2	13	237	Easy.
Zeta Cancri	5·6, 6·1	5·6	082	
Iota Cancri	4·4, 6·5	31	307	Easy. Yellow, blue.
Alpha Canum Venat.	3·2, 5·7	20	228	Yellowish, bluish. Easy.
Alpha Capricorni	3·2, 4·2	376	291	Naked-eye pair. Alpha again double.
Eta Cassiopeiæ	3·7, 7·4	11	298	Creamy, bluish. Easy.
Beta Cephei	3·3, 8·0	14	250	
Delta Cephei	var, 7·5	41	192	Very easy.
Xi Cephei	4·7, 6·5	6	270	Reasonably easy.
Gamma Ceti	3·7, 6·2	3	300	Not too easy.
Zeta Coronæ Borealis	4·0, 4·9	6·3	304	
Delta Corvi	3·0, 8·5	24	212	
Beta Cygni	3·0, 5·3	35	055	Yellow, green. Glorious.
61 Cygni	5·3, 5·9	25	150	
Gamma Delphini	4·0, 5·0	10	265	Yellow, greenish. Easy.
Nu Draconis	4·6, 4·6	62	312	Naked-eye pair.
Alpha Geminorum	2·0, 2·8	2	151	Castor. Becoming easier.
Delta Geminorum	3·2, 8·2	6·5	120	
Alpha Herculis	var, 6·1	4·5	110	Red, green.
Delta Herculis	3·0, 7·5	11	208	Optical double.
Zeta Herculis	3·0, 6·5	1·4	300	Fine, rapid binary.
Gamma Leonis	2·6, 3·8	4·3	121	Binary; period 400 years.
Alpha Lyræ	0·0, 10·5	60	180	Vega. Optical; B faint.
Epsilon Lyræ	4·6, 6·3	3	005	Quadruple. Both pairs
	4·9, 5·2	2·3	111	separable in 3 in. OG
Zeta Lyræ	4·2, 5·5	44	150	Fixed. Easy double.
Beta Orionis	0·1, 6·7	9·5	205	Rigel. Can be split with 3 in.
Iota Orionis	3·2, 7·3	11	140	

SOME INTERESTING CLUSTERS AND NEBULÆ

Name	*Magnitudes*	*Separation,"*	*Position angle, deg.*	*Remarks*
Theta Orionis	6·0, 7·0 7·5, 8·0			The famous Trapezium in M.42
Sigma Orionis	4·0, 7·0 7·5, 10·0	11·1 12·9	236 085	Quadruple. D is rather faint in small apertures.
Zeta Orionis	1·9, 5·0	3	160	
Eta Persei	4·0, 8·5	8·5	300	Yellow, bluish.
Alpha Piscium	4·3, 5·3	1·9	291	
Alpha Scorpii	0·9, 6·8	3	275	Antares, Red. green.
Nu Scorpii	4·2, 6·5	42	336	
Theta Serpentis	4·1, 4·1	23	103	Very easy.
Alpha Tauri	0·8, 11·2	130	032	Aldebaran. Wide, but B is very faint in small telescopes.
Zeta Ursæ Majoris	2·3, 4·2	14·5	150	Mizar. Very easy. Naked eye pair with Alcor.
Alpha Ursæ Minoris	2·0, 9·0	18·3	217	Polaris. Can be seen with 3 in.
Gamma Virginis	3·6, 3·7	4·8	305	Binary; period 180 yrs. Closing.
Theta Virginis	4·0, 9·0	7	340	Not too easy.

Some Interesting Clusters and Nebulæ

Object	R.A.		Dec.		*Remarks*
	h	*m*	°	′	
M.31 Andromedæ	00	40·7	+41	05	Great Galaxy, visible to naked eye.
H.VIII 78 Cassiopeiæ	00	41·3	+61	36	Fine cluster, between Gamma and Kappa Cassiopeiæ.
M.33 Trianguli	01	31·8	+30	28	Spiral. Difficult with small apertures.
H.VI 33–4 Persei	02	18·3	+56	59	Double cluster; Sword-handle.
M.1 Tauri	05	32·3	+22	00	Crab Nebula, near Zeta Tauri.
M.42 Orionis	05	33·4	−05	24	Great Nebula. Contains the famous Trapezium, Theta Orionis.
M.35 Geminorum	06	06·5	+24	21	Open cluster near Eta Geminorum.
H.VII 2 Monocerotis	06	30·7	+04	53	Open cluster, just visible to naked eye.
M.41 Canis Majoris	06	45·5	−20	42	Open cluster, just visible to naked eye.
M.44 Cancri	08	38	+20	07	Præsepe. Open cluster near Delta Cancri. Visible to naked eye.
M.97 Ursæ Majoris	11	12·6	+55	13	Owl Nebula, diameter 3′. Planetary.
M.3 Canum Venaticorum	13	40·6	+28	34	Bright globular.
M.80 Scorpionis	16	14·9	−22	53	Globular, between Antares and Beta Scorpionis.
M.4 Scorpionis	16	21·5	−26	26	Open cluster close to Antares.
M.13 Herculis	16	40	+36	31	Globular. Just visible to naked eye.
M.92 Herculis	17	16·1	+43	11	Globular. Between Iota and Eta Herculis.
M.7 Scorpionis	17	51·6	−34	48	Fine open cluster. Very low in England.
M.23 Sagittarii	17	54·8	−19	01	Open cluster nearly 50′ in diameter.
H.VI 37 Draconis	17	58·6	+66	38	Bright Planetary.
M.8 Sagittarii	18	01·4	−24	23	Lagoon Nebula. Gaseous. Just visible with naked eye.
NGC 6572 Ophiuchi	18	10·9	+06	50	Bright planetary, between Beta Ophiuchi and Zeta Aquilæ.
M.17 Sagittarii	18	18·8	−16	12	Omega Nebula. Gaseous. Large and bright.
M.11 Scuti	18	49·0	−06	19	Wild Duck. Bright open cluster.
M.57 Lyræ	18	52·6	+32	59	Ring Nebula. Brightest of planetaries.
M.27 Vulpeculæ	19	58·1	+22	37	Dumb-bell Nebula, near Gamma Sagittæ
H.IV 1 Aquarii	21	02·1	−11	31	Bright planetary near Nu Aquarii.
M.15 Pegasi	21	28·3	+12	01	Bright globular, near Epsilon Pegasi.
M.39 Cygni	21	31·0	+48	17	Open cluster between Deneb and Alpha Lacertæ. Well seen with low powers.

PART FOUR

Miscellaneous

Some Recent Books

Meteorites and their Origins, by G. J. H. McCall. David & Charles, 1973. A comprehensive account, by the former Reader in Geology at the University of Western Australia. Dr McCall is one of the world's foremost experts in the study of meteorites.

Astronomy Data Book, by J. Hedley Robinson. David & Charles, 1973. A reference book ranging over all branches of astronomy; quite invaluable for anyone who wants to 'look up facts'. The author is Director of the Mercury and Venus Section of the British Astronomical Association.

Mars Flight Atlas, by C. A. Cross and Patrick Moore. Mitchell Beazley, 1973. The first atlas of Mars incorporating all the details obtained from the Mariner 9 photographs; also included are many actual photographs and explanatory diagrams.

Galaxies, by Harlow Shapley. Oxford, 1973. A new edition of this classic book. The revisions have been undertaken by Paul W. Hodge; but the book in its style, content, clarity, and authority is still unmistakably Shapley's own.

Our Contributors

Dr David A. Allen was born in 1946, and educated at Manchester Grammar School and Cambridge University. He took his B.A. in theoretical physics in 1967, and his Ph.D. in 1971; the subject of his thesis was the infrared radiation of the unlit Moon. He took up a Carnegie Fellowship at the Hale Observatories from 1970 to 1972, and became a Junior Research Fellow at the Royal Greenwich Observatory in October 1972. His observing interests include infrared astronomy and low-resolution spectroscopy. His recent work has been concentrated on emission-line stars, and he has discovered several infrared sources. Telescopes used include the Palomar 200-in., the Mount Wilson 100-in., and 60-in., and the Isaac Newton 98-in.

Simon Mitton, M.A., Ph.D., M.Inst.P., is also a Cambridge graduate, and carried out research on radio galaxies until 1971. He is Secretary of the Institute of Astronomy at Cambridge, and is the U.K. editor of *Astrophysical Letters.*

H. G. Miles, B.E.M., B.Sc., Lecturer in Mathematics at the Lanchester College of Technology in Coventry, is the Director of the Artificial Satellite Section of the British Astronomical Association. His other astronomical interests include studies of fireballs and meteors. He is the author of many scientific papers, both popular and technical.

Nicholas J. A. Tate is currently graduating at the University of St Andrews. His interests range over many branches of science, but he concentrates largely upon radio astronomy.

GILBERT E. SATTERTHWAITE was formerly a professional astronomer at the Royal Greenwich Observatory – and it was he who made the last official observation with the Airy Transit Circle! Subsequently he entered scientific publishing, a career which he still pursues. He is Director of the Saturn Section of the British Astronomical Association, and is the author of many papers as well as a noted book, *Encyclopedia of Astronomy*. He lives at Orpington, in Kent.

DR VINICIO BAROCAS is Italian by birth, but has lived in England for many years, and is Director of the Jeremiah Horrocks and Wilfred Hall Observatories at Preston in Lancashire. He is a world expert in connection with studies of the Sun and with astrophysics in general. In addition he is a leading popularizer of astronomy, who has written many books for laymen; and he is a frequent broadcaster.

Astronomical Societies in Great Britain

The advantages of joining an astronomical society are obvious enough. Full information about national and local Societies was given in the 1966 *Yearbook;* a condensed list, suitably brought up to date, is given below.

Name	*Secretarial Address*	*Yearly Subscription* §=members under 18, or 'juniors'	*Meeting Time and Place*
British Astronomical Association	**Burlington House, Piccadilly, London, W.1. (J. L. White)**	**£3·25 (§£2·50)**	**Burlington House, Piccadilly Last Wed. each month (Oct-June)**
Junior Astronomical Society	**58 Vaughan Gardens, Ilford, Essex**	**£1**	**Alliance Hall, Palmer St., WC1 Last Saturday Jan., April, July, Oct. 2.30 p.m.**
Aberdeen and District Astronomical Society	**14 Abbotshall Gardens, Cults, Aberdeen (W. P. Cooper)**		**Robert-Gordon's Institute of Technology, St Andrew Street, Aberdeen**
Altrincham and District Astronomical Society	**10 Delamere Road, Gatley, Cheadle, Cheshire (Colin Henshaw)**	**25p**	**Park Road Library, Timperley 1st Friday of each month 7.30 p.m.**
Aylesbury Astronomical Society	**9 Elm Close, Butler's Cross, Aylesbury (N. Neale)**	**£1**	**As arranged**
Birmingham Astronomical Society	**17 Hannafore Road, Edgbaston, (W. E. Marsh)**	**£1 (§25p)**	**Birmingham and Midland Institute Monthly**
Bridgwater Astronomical Society	**The Technical College, Broadway, Bridgwater, Somerset**	**50p**	**A.T.C. H.Q., Rope Walk, Bridgwater, 3rd Thursday in each month**
Brighton Astronomical Society	**6 Old Shoreham Road, Hove 4, Sussex (Brigadier V. M. Papworth)**		
Bristol Astronomical Society	**34 Butterfield Close, Bristol BS10 5AZ (G. H. Woodman)**	**£2·50 (§52½p)**	**Royal Fort (Rm G44) Bristol University last Friday each month, Sept.-May**
Caithness and Dounreay Astronomical Society	**Room 31, Ormlie Lodge, Thurso, Scotland (Miss M. J. A. Clark)**	**£1**	**Fortnightly**
Camberley (Surrey) Astronomical Society	**75 Christchurch Drive, Blackwater, Surrey (Ron Toft)**	**50p (§20p)**	**Watchetts Middle School, Frimley Road, Surrey Monthly**
Cambridge Astronomical Society	**5 Haggis Gap, Fulbourn (S. R. Whistler)**	**£1·05 (§37½p)**	**7 Brooklands Avenue, Cambridge 2nd Mon. each month Oct.-July**
Chelmsford and District Astronomical Society	**70 Maldon Road, Burnham-on-Crouch (Miss C. C. Puddick)**	**£1 (§50p)**	**Sandon House School, Chelmsford Last Mon. in month 7.30 p.m.**

Name	*Secretarial Address*	*Yearly Subscription* § = members under 18, or 'juniors'	*Meeting Time and Place*
Chester Astronomical Society	37 Alwyn Gardens, Upton, Chester (A. Kemp)	£1 (§50p)	St Andrews House, Newgate St., Chester Monthly
Chester Society of Natural Science, Literature and Art	Wood Farm, Tattenhall Lanes, Tattenhall, nr Chester (Geoffrey Lake)	—	Grosvenor Museum, Chester Fortnightly
Chesterfield Astronomical Society	Hilltop Cottage. Gallery Lane, Holymoorside, Chesterfield (Mrs R. C. Naylor)	£1 (§50p)	Barnett Observatory, Newbold Each Friday
Clackmannanshire Astronomical Society	9 Deer Park, Sauchie, Alloa (J. Cluckie)	£1	St Mary's School, Alloa Monthly, 3rd Friday Sept.-May
Cleethorpes Astronomical Society	95 Sandringham Road, Cleethorpes, Lincolnshire (W. S. Cobley)	£1 (§50p)	Dolphin Hotel, Cleethorpes Monthly
Crawley Astronomical Society	Crawley College of Further Education, Sussex (F. D. Cooper)	37p	Crawley College of Further Education Monthly
Crayford Manor House Astronomical Society	Manor House Centre, Crayford, Kent (R. H. Chambers)	None	Manor House Centre, Crayford Monthly during term-time
Croydon Astronomical Society	12 Elstan Way, Shirley, Croydon (K.E. Stanbridge)	— 5p entrance fee to meetings	The Old Whitgiftian Sports Club, Lime Meadow Ave., Sanderstead, Surrey Alternate Fridays 7.45 p.m.
Dundee Astronomical Society	4 Finlaggan Place, Dundee, Scotland (D. Gavine)	50p (§25p)	Mill's Observatory, Dundee Fortnightly in the winter
Eastbourne Astronomical Society	80 Ringwood Road, Eastbourne, Sussex (W. O. Tutt)	£1·05 (§52½p)	As arranged Monthly
East Lancashire Astronomical Society	95 Accrington Road, Blackburn (L. Willan)	£1 (§37½p)	Longridge Observatory Preston
Astronomical Society of Edinburgh	126 W. Saville Terrace, Edinburgh 9, Scotland (N. G. Matthew)	£1	Calton Hill Observatory, Edinburgh Monthly
Ewell Astronomical Society	11 Elmwood Drive, Ewell, Surrey (L. J. Bentley)	£1 (§50p)	Ewell County Technical College, Reigate Road, Ewell, Surrey 1st Friday of each month
Fellowship of Junior Astronomers, Edinburgh	58 Ogilvie Terrace, Edinburgh 11, Scotland (Miss Edith McLean)	37½p	Calton Hill Observatory, Edinburgh 2nd Sat. each month, Sept.-June
Fylde Astronomical Society	28 Belvedere Rd, Thornton, Lancs (—)	£1 (§50p)	Stanley Hall, Rossendale Ave. South 1st Wed. each month
Astronomical Society of Glasgow	108 Tannahill Drive, Calderwood 12, East Kilbride, Glasgow G74 3HT (A. Thomson)	50p	Roy. Coll. Science and Tech., Glasgow 3rd Thur. each month, Sept.-April

Name	*Secretarial Address*	*Yearly Subscription* §=members under 18, or 'juniors'	*Meeting Time and Place*
Great Yarmouth Astronomical Society	38 Cobholm Road, Cobholm, Great Yarmouth, Norfolk (M. Poxon)	(To be announced)	(To be announced)
Guildford Astronomical Society	12 Durham Close, Guildford (Mrs. D. E. Clapson)	£1	Corona Restaurant, High Street, Guildford 1st Tue. each month 7.45 p.m.
Herschel Society	35 Kendal Drive, Slough (C. Wise)	—	(To be announced)
Isle of Wight Astronomical Society	1 Hilltop Cottages, High Street, Freshwater, Isle of Wight (J. W. Feakins)	£1 (§50p)	Unitarian Church Hall, Newport, Isle of Wight Monthly
Leeds Astronomical Society	Maths. Dept., The University, Leeds 2 (B. L. Meek)	50p (§25p)	Leeds University Six annually
Leicester Astronomical Society	26 Falmouth Rd., Evington, Leicester (Mrs L. Withey)	£1·05 (37p)	Leicester Museum and Art Gallery Monthly
Lincoln Astronomical Society	344 Brant Road, Lincoln (P. Hammerton)	£1 (§25p)	Lincoln YMCA Hall 1st Tue. each month
Liverpool Astronomical Society	Simms Cross School Hse., Mitton Road, Widnes (D. Bradburne)	£1·50 (§75p)	City Museum, Liverpool Monthly
Loughton Astronomical Society	Aldersbrook House, Romford Road, Manor Park, E12 5LN (D. E. Brede)	£1·50 (§£1)	Loughton Hall, Rectory Lane, Loughton, Essex Thursdays, 8 p.m.
Luton Astronomical Society	20 Bloomfield Avenue, Luton (S. J. Anderson)	£1	Last Friday each month
Maidenhead Astronomy Group	129 Fane Way, Maidenhead, Berkshire (S. A. H. Roper)	50p (§12½p)	Maidenhead Grammar School Once every 3 weeks
Manchester Astronomical Society	Cragside, Cliff Avenue, Summerseat, Bury (Alan Whittaker)	£1 (§50p)	Godlee Observatory, Manchester 1 Weekly
Mansfield and District Astronomical Society	14 Bonnington Crescent, Sherwood Estate, Nottingham (G. W. Shepherd)	50p (§25p)	Monks Precision Engineering Co., Mansfield Rd., Sutton-in-Ashfield Last Monday of each calendar month
Mid-Sussex Astronomical Society	19 Blackthorns, Lindfield, Sussex (G. A. N. Molloy)	£2 (§£1)	Haywards Heath Grammar School Wednesdays 7.30 p.m.
Milton Keynes Astronomical Society	1 Kennet Drive, Bletchley, Milton Keynes	10p (§5p) per meeting	Alternate Tuesdays
Newcastle-on-Tyne Astronomical Society	30 Kew Gardens, Whitley Bay, Northumberland (G. E. Manville)	£1	Botany Lecture Theatre Newcastle University Monthly, Sept.-April
Newtonian Observatory Astronomical Society	62 Northcott Road, Worthing, Sussex (Miss P. E. Randle)	£1·20	Adult Education Centre Union Place, Worthing 1st Wed. each month except Aug. 7.30 p.m.

Name	*Secretarial Address*	*Yearly Subscription* §=members under 18, or 'juniors'	*Meeting Time and Place*
North Dorset Astronomical Society	The Pharmacy, Stalbridge, Dorset (J. E. M. Coward)	—	Charterhay, Stourton, Caundle, Dorset 2nd Wed. each month
Norwich Astronomical Society	The Manse, Back Lane, Wymondham, Norwich	£1 (§50p)	The Observatory, Daniels Rd., Norwich 1st Tues. each month Sept.-May
Nottingham Astronomical Society	18 Naseby Close, Heathfield, Nottingham (C. Swift)	£1·25p	Monthly
Orwell Astronomical Society (Ipswich)	33 Crofton Road, Ipswich, Suffolk (M. Hadden)	£1·05 (§5p)	Orwell Park School Nacton, Ipswich Weekly
Oxshott Astronomical Group	Norman Cottage, Pond Piece, Sheath Lane, Oxshott, Surrey (E. H. Noon)	50p	Oxshott Village Centre 1st Wed. each month Sept.-May
Paisley Astronomical Society	14 Cheviot Avenue, Barrhead, Glasgow (Mrs J. Holms)	£1 (§50p)	Coats Observatory, 49 Oakshaw Street, Paisley Monthly
Peterborough Astronomical Society	24 Cissbury Ring Werrington, Peterborough (E. Pitchford)	£1·25 (§25p)	Peterborough Technical College 2nd Tues., 3rd Thur. each month
Plymouth Astronomical Society	1 Valletort Cotts, Millbridge, Plymouth (G. S. Pearce)		Plymouth College of Technology, Tavistock Road, Plymouth Monthly
Portsmouth Astronomical Group	52 Denbigh Drive, Fareham, Hampshire (S. W. Hackman)	£3	The Group Observatory
Portsmouth Astronomical Society	91 Sutherland Road, Southsea (P. R. Seiden)	£1·50	Monday Fortnightly
Preston and District Astronomical Society	35 Bispham Road, Carleton, Poulton-le-Fylde, Lancs (C. Lynch)	£1 (§25p)	Chamber of Commerce, 49a Fishergate, Preston 3rd Mon. each month Sept.-May
Rayleigh Centre Amateur Astronomical Society	51 Rayleigh Avenue, Eastwood, Leigh on Sea, Essex (D. C. J. Watkins)	£1·50 (80p)	Fitzwimarc School, Hockley Road, Rayleigh. Every Wed., 8 p.m.
Reading Astronomical Society	30 Amherst Road, Reading (J. Wrigley)	75p (§25p)	Anderson Baptist Church Hall, Reading Monthly
Salford Astronomical Society	44 Pevensey Road, Salford 6 (A. Taylor)	£1 (§50p)	The Observatory, 3rd Wed. each month
Salisbury Plain Astronomical Society	St George's Cottage, Orcheston, Salisbury, Wilts. (R. J. D. Nias)	50p (§25p)	St George's Rectory Orcheston Quarterly
Slough Astronomical Society	The Elms, Odds Farm, Green Common Lane, Wooburn Common, High Wycombe, Bucks (E. Shilton)	£1	Monthly
Solent Amateur Astronomers	14 Orchard Avenue, Bishopstoke, Eastleigh, Hants. (R. W. Arbour)	£1.50 (§75p)	Millbrook School, Lower Brownhills Rd., Maybush, Southampton, 3rd Thur. each month. Observational sessions as arranged

Name	*Secretarial Address*	*Yearly Subscription* § = members under 18, or 'juniors'	*Meeting Time and Place*
South Downs Astronomical Society	6 Queensfield East, West Meads, Bognor Regis	£2 (§£1)	Last Friday in each month
Southampton Astronomical Society	4 Heathfield, Dibden Purlieu, Southampton (J. G. Thompson)	£2 (§£1)	2nd Thur. each month Unigate Conference Room, Southampton 4th Thursday each month Room 33, University of Southampton
South-East Kent Astronomical Society	20 Cumberland Avenue, South Benfleet, Essex (A. R. Welsh)	(To be arranged)	
Southport Astronomical Society	4 Warren Green, Freshfield, Lancs. (M. Bloch)	75p	As arranged Monthly
South Shields Astronomical Society	Marine and Technical College, St George's Ave., South Shields, Co. Durham (H. Haysham)	£1 (37½p)	Marine and Technical College Each Thursday, 7.30 p.m.
South West Herts Astronomical Society	32 Riverford Close, Harpenden, Herts. (G. J. B. Phillips)	£1·50 (§75p)	Royal Masonic School for Girls, Rickmansworth Last Fri. each month Sept.-May
Stoke-on-Trent Astronomical Society	Sundale, Dunnocksfold Road, Alsager, Stoke (M. Pace)	75p	Cartwright House, Broad Street, Hanley Monthly
Swansea Astronomical Society	30 Cwpt-y-Clafdy, Skewen, nr Heath, Glamorganshire (C. Morris)	£1·50 (§25p) Students 50p	As arranged
Thanet Amateur Astronomical Society	85 Crescent Road, Ramsgate (P. F. Jordan)	25p	Hilderstone House, Broadstairs, Kent Monthly
Torbay Astronomical Society	4 Heath Rise, Brixham, Devon (Miss A. Longman)	75p (§25p)	Quay Tor Hotel, Scarborough Road, Torquay. Monthly
Waltham Forest and District Junior Astronomy Club	24 Fulbourne Road, Walthamstow, London E17 (B. Crawford)	50p	24 Fulbourne Road, Walthamstow, London E17 Fortnightly (Mondays)
Warrington Astronomical Society	2 Dale Avenue, Appleton, Warrington (B. P. Rees)	£1	Central Library, Museum Street, Warrington, Lancs Monthly, Sept.-May
Warwickshire Astronomical Society	20 Humber Road, Coventry, Warwickshire (R. D. Wood)	£4	20 Humber Road, Coventry Each Tuesday
Wolverhampton Astronomical Society	Garwick, 8 Holme Mill, Fordhouses, Wolverhampton (M. Astley)	£1	38 Tettenhall Road, Wolverhampton Alternate Mon., Sept.-April
Webb Society	7 Elvendon Road, Palmers Green, London, N.13 (E. Moore)	£1 (§75p)	As arranged
Wessex Astronomical Group	St Catherine's Court, D4, 35 Christchurch Road, Bournemouth (Mrs H. Bagainy)	—	Ashley Cross Girls School, Lower Parkstone, Poole, Dorset 1st Tues. each month (except Aug.) 7.30 p.m.

Name	*Secretarial Address*	*Yearly Subscription* §=members under 18, or 'juniors'	*Meeting Time and Place*
West of London Astronomical Society	5 Blakesley Avenue, Ealing, W5 2DN (P. Macdonald)	40p	Monthly, alternately at Ruislip and North Harrow 2nd Monday of the month (except August)
West Yorkshire Astonomical Society	76 Katrina Grove, Purston, Pontefract, Yorks. (Jim Roberts)	50p (§25p) entrance fee 10p (§5p) per meeting	Carleton Boys School, Pontefract Fortnightly
Wyvern Astronomical Society	2 Howcroft, Churchdown, Gloucester (A. F. Edwards)	75p (§25p)	Clubhouse, Churcham Last Friday of each month except Aug.
Zenith Astronomical Society	10 Meadow Close, Reedby, nr Burnley (A. Harvey)	—	54 Cromwell Street, Burnley 1st Wednesday in each month

It is possible that this list of local societies may not be quite complete. If any have been omitted, the secretaries concerned are invited to write to the Editor (c/o Messrs Sidgwick & Jackson (Publishers), Ltd, 1 Tavistock Chambers, Bloomsbury Way, London WC1), so that the relevant notes may be included in the 1975 *Yearbook*.

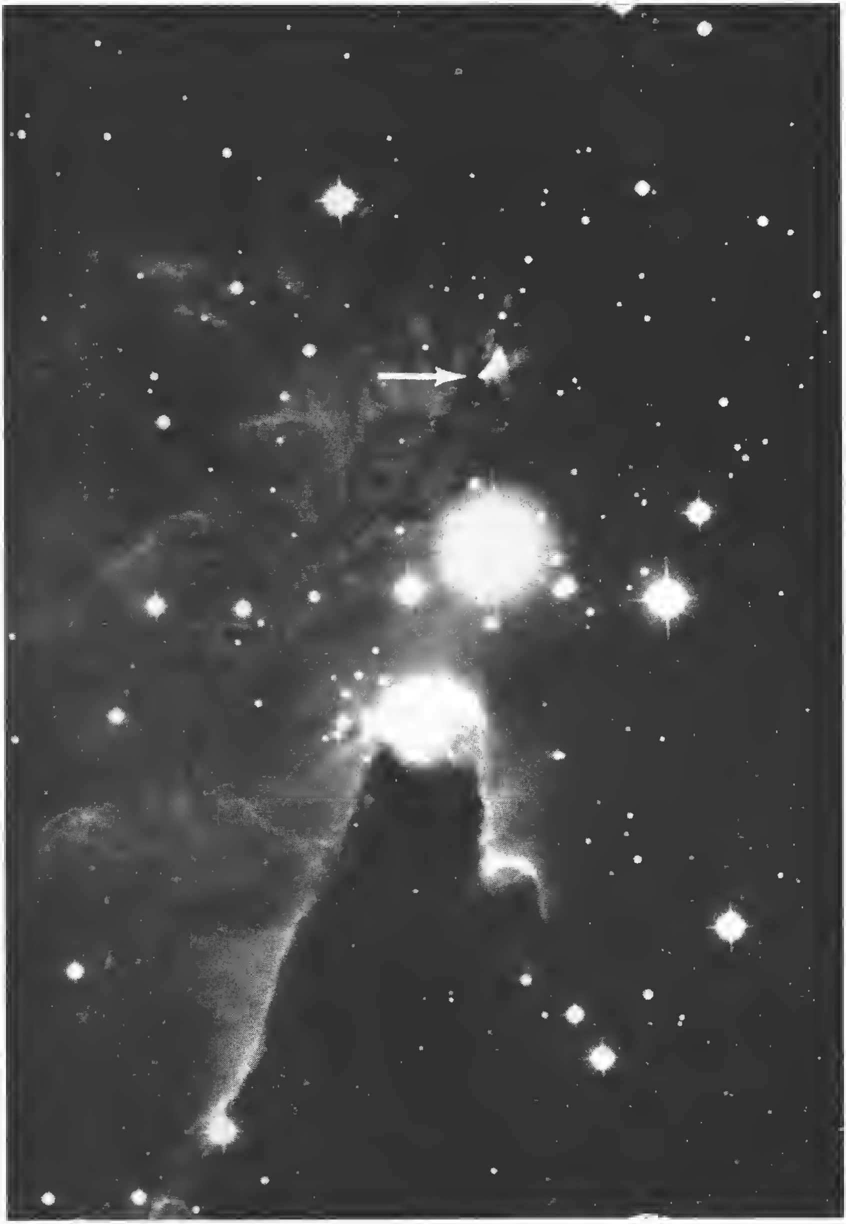


Fig. 1. The southern section of NGC 2264 photographed in the red Hα line of hydrogen. The position of the infrared source discovered by the author is marked by an arrow. Palomar 200-inch photograph courtesy of the Hale Observatories. (See page 163.)

Edited by Patrick Moore
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1974

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